DAQ

NI 435*x* User Manual

High-Precision Temperature and Voltage Meters

March 2005
370841B-01

NATIONAL INSTRUMENTS™

Worldwide Technical Support and Product Information

ni.com

National Instruments Corporate Headquarters

11500 North Mopac Expressway Austin, Texas 78759-3504 USA Tel: 512 683 0100

Worldwide Offices

Australia 1800 300 800, Austria 43 0 662 45 79 90 0, Belgium 32 0 2 757 00 20, Brazil 55 11 3262 3599, Canada 800 433 3488, China 86 21 6555 7838, Czech Republic 420 224 235 774, Denmark 45 45 76 26 00, Finland 385 0 9 725 725 11, France 33 0 1 48 14 24 24, Germany 49 0 89 741 31 30, India 91 80 51190000, Israel 972 0 3 6393737, Italy 39 02 413091, Japan 81 3 5472 2970, Korea 82 02 3451 3400, Lebanon 961 0 1 33 28 28, Malaysia 1800 887710, Mexico 01 800 010 0793, Netherlands 31 0 348 433 466, New Zealand 0800 553 322, Norway 47 0 66 90 76 60, Poland 48 22 3390150, Portugal 351 210 311 210, Russia 7 095 783 68 51, Singapore 1800 226 5886, Slovenia 386 3 425 4200, South Africa 27 0 11 805 8197, Spain 34 91 640 0085, Sweden 46 0 8 587 895 00, Switzerland 41 56 200 51 51, Taiwan 886 02 2377 2222, Thailand 662 992 7519, United Kingdom 44 0 1635 523545

For further support information, refer to the *Technical Support and Professional Services* appendix. To comment on National Instruments documentation, refer to the National Instruments Web site at ni.com/info and enter the info code feedback.

© 2003–2005 National Instruments Corporation. All rights reserved.

Important Information

Warranty

The NI 4350 and NI 4351 devices are warranted against defects in materials and workmanship for a period of one year from the date of shipment, as evidenced by receipts or other documentation. National Instruments will, at its option, repair or replace equipment that proves to be defective during the warranty period. This warranty includes parts and labor.

The media on which you receive National Instruments software are warranted not to fail to execute programming instructions, due to defects in materials and workmanship, for a period of 90 days from date of shipment, as evidenced by receipts or other documentation. National Instruments will, at its option, repair or replace software media that do not execute programming instructions if National Instruments receives notice of such defects during the warranty period. National Instruments does not warrant that the operation of the software shall be uninterrupted or error free.

A Return Material Authorization (RMA) number must be obtained from the factory and clearly marked on the outside of the package before any equipment will be accepted for warranty work. National Instruments will pay the shipping costs of returning to the owner parts which are covered by warranty.

National Instruments believes that the information in this document is accurate. The document has been carefully reviewed for technical accuracy. In the event that technical or typographical errors exist, National Instruments reserves the right to make changes to subsequent editions of this document without prior notice to holders of this edition. The reader should consult National Instruments if errors are suspected. In no event shall National Instruments be liable for any damages arising out of or related to this document or the information contained in it.

EXCEPT AS SPECIFIED HEREIN, NATIONAL INSTRUMENTS MAKES NO WARRANTIES, EXPRESS OR IMPLIED, AND SPECIFICALLY DISCLAIMS ANY WARRANTY OF MERCHANTABILITY OR FITNESS FOR A PARTICULAR PURPOSE. CUSTOMER'S RIGHT TO RECOVER DAMAGES CAUSED BY FAULT OR NEGLIGENCE ON THE PART OF NATIONAL INSTRUMENTS SHALL BE LIMITED TO THE AMOUNT THERETOFORE PAID BY THE CUSTOMER. NATIONAL INSTRUMENTS WILL NOT BE LIABLE FOR DAMAGES RESULTING FROM LOSS OF DATA, PROFITS, USE OF PRODUCTS, OR INCIDENTAL OR CONSEQUENTIAL DAMAGES, EVEN IF ADVISED OF THE POSSIBILITY THEREOF. This limitation of the liability of National Instruments will apply regardless of the form of action, whether in contract or tort, including negligence. Any action against National Instruments must be brought within one year after the cause of action accrues. National Instruments shall not be liable for any delay in performance due to causes beyond its reasonable control. The warranty provided herein does not cover damages, defects, malfunctions, or service failures caused by owner's failure to follow the National Instruments installation, operation, or maintenance instructions; owner's modification of the product; owner's abuse, misuse, or negligent acts; and power failure or surges, fire, flood, accident, actions of third parties, or other events outside reasonable control.

Copyright

Under the copyright laws, this publication may not be reproduced or transmitted in any form, electronic or mechanical, including photocopying, recording, storing in an information retrieval system, or translating, in whole or in part, without the prior written consent of National Instruments Corporation.

Trademarks

National Instruments, NI, ni.com, and LabVIEW are trademarks of National Instruments Corporation. Refer to the *Terms of Use* section on `ni.com/legal` for more information about National Instruments trademarks.

Other product and company names mentioned herein are trademarks or trade names of their respective companies.

Members of the National Instruments Alliance Partner Program are business entities independent from National Instruments and have no agency, partnership, or joint-venture relationship with National Instruments.

Patents

For patents covering National Instruments products, refer to the appropriate location: **Help»Patents** in your software, the `patents.txt` file on your CD, or `ni.com/patents`.

WARNING REGARDING USE OF NATIONAL INSTRUMENTS PRODUCTS

(1) NATIONAL INSTRUMENTS PRODUCTS ARE NOT DESIGNED WITH COMPONENTS AND TESTING FOR A LEVEL OF RELIABILITY SUITABLE FOR USE IN OR IN CONNECTION WITH SURGICAL IMPLANTS OR AS CRITICAL COMPONENTS IN ANY LIFE SUPPORT SYSTEMS WHOSE FAILURE TO PERFORM CAN REASONABLY BE EXPECTED TO CAUSE SIGNIFICANT INJURY TO A HUMAN.

(2) IN ANY APPLICATION, INCLUDING THE ABOVE, RELIABILITY OF OPERATION OF THE SOFTWARE PRODUCTS CAN BE IMPAIRED BY ADVERSE FACTORS, INCLUDING BUT NOT LIMITED TO FLUCTUATIONS IN ELECTRICAL POWER SUPPLY, COMPUTER HARDWARE MALFUNCTIONS, COMPUTER OPERATING SYSTEM SOFTWARE FITNESS, FITNESS OF COMPILERS AND DEVELOPMENT SOFTWARE USED TO DEVELOP AN APPLICATION, INSTALLATION ERRORS, SOFTWARE AND HARDWARE COMPATIBILITY PROBLEMS, MALFUNCTIONS OR FAILURES OF ELECTRONIC MONITORING OR CONTROL DEVICES, TRANSIENT FAILURES OF ELECTRONIC SYSTEMS (HARDWARE AND/OR SOFTWARE), UNANTICIPATED USES OR MISUSES, OR ERRORS ON THE PART OF THE USER OR APPLICATIONS DESIGNER (ADVERSE FACTORS SUCH AS THESE ARE HEREAFTER COLLECTIVELY TERMED "SYSTEM FAILURES"). ANY APPLICATION WHERE A SYSTEM FAILURE WOULD CREATE A RISK OF HARM TO PROPERTY OR PERSONS (INCLUDING THE RISK OF BODILY INJURY AND DEATH) SHOULD NOT BE RELIANT SOLELY UPON ONE FORM OF ELECTRONIC SYSTEM DUE TO THE RISK OF SYSTEM FAILURE. TO AVOID DAMAGE, INJURY, OR DEATH, THE USER OR APPLICATION DESIGNER MUST TAKE REASONABLY PRUDENT STEPS TO PROTECT AGAINST SYSTEM FAILURES, INCLUDING BUT NOT LIMITED TO BACK-UP OR SHUT DOWN MECHANISMS. BECAUSE EACH END-USER SYSTEM IS CUSTOMIZED AND DIFFERS FROM NATIONAL INSTRUMENTS' TESTING PLATFORMS AND BECAUSE A USER OR APPLICATION DESIGNER MAY USE NATIONAL INSTRUMENTS PRODUCTS IN COMBINATION WITH OTHER PRODUCTS IN A MANNER NOT EVALUATED OR CONTEMPLATED BY NATIONAL INSTRUMENTS, THE USER OR APPLICATION DESIGNER IS ULTIMATELY RESPONSIBLE FOR VERIFYING AND VALIDATING THE SUITABILITY OF NATIONAL INSTRUMENTS PRODUCTS WHENEVER NATIONAL INSTRUMENTS PRODUCTS ARE INCORPORATED IN A SYSTEM OR APPLICATION, INCLUDING, WITHOUT LIMITATION, THE APPROPRIATE DESIGN, PROCESS AND SAFETY LEVEL OF SUCH SYSTEM OR APPLICATION.

Compliance

Compliance with FCC/Canada Radio Frequency Interference Regulations

Determining FCC Class

The Federal Communications Commission (FCC) has rules to protect wireless communications from interference. The FCC places digital electronics into two classes. These classes are known as Class A (for use in industrial-commercial locations only) or Class B (for use in residential or commercial locations). All National Instruments (NI) products are FCC Class A products.

Depending on where it is operated, this Class A product could be subject to restrictions in the FCC rules. (In Canada, the Department of Communications (DOC), of Industry Canada, regulates wireless interference in much the same way.) Digital electronics emit weak signals during normal operation that can affect radio, television, or other wireless products.

All Class A products display a simple warning statement of one paragraph in length regarding interference and undesired operation. The FCC rules have restrictions regarding the locations where FCC Class A products can be operated.

Consult the FCC Web site at `www.fcc.gov` for more information.

FCC/DOC Warnings

This equipment generates and uses radio frequency energy and, if not installed and used in strict accordance with the instructions in this manual and the CE marking Declaration of Conformity*, may cause interference to radio and television reception. Classification requirements are the same for the Federal Communications Commission (FCC) and the Canadian Department of Communications (DOC).

Changes or modifications not expressly approved by NI could void the user's authority to operate the equipment under the FCC Rules.

Class A

Federal Communications Commission

This equipment has been tested and found to comply with the limits for a Class A digital device, pursuant to part 15 of the FCC Rules. These limits are designed to provide reasonable protection against harmful interference when the equipment is operated in a commercial environment. This equipment generates, uses, and can radiate radio frequency energy and, if not installed and used in accordance with the instruction manual, may cause harmful interference to radio communications. Operation of this equipment in a residential area is likely to cause harmful interference in which case the user is required to correct the interference at their own expense.

Canadian Department of Communications

This Class A digital apparatus meets all requirements of the Canadian Interference-Causing Equipment Regulations.

Cet appareil numérique de la classe A respecte toutes les exigences du Règlement sur le matériel brouilleur du Canada.

Compliance with EU Directives

Users in the European Union (EU) should refer to the Declaration of Conformity (DoC) for information* pertaining to the CE marking. Refer to the Declaration of Conformity (DoC) for this product for any additional regulatory compliance information. To obtain the DoC for this product, visit `ni.com/certification`, search by model number or product line, and click the appropriate link in the Certification column.

* The CE marking Declaration of Conformity contains important supplementary information and instructions for the user or installer.

Contents

About This Manual

Conventions ix
Related Documentation x
Examples x

Chapter 1
Introduction

About the NI 435*x* High-Precision DAQ Devices 1-1
Using PXI with CompactPCI 1-2
Configuration 1-2
Software Options for the NI 435*x* 1-2
What Is the NI-435*x* Instrument Driver? 1-2
What Is LabVIEW? 1-3
What Is LabWindows/CVI? 1-3
What Is VI Logger? 1-3
Installing the Software 1-3
Installing the Hardware 1-4
NI PXI-4351 1-4
NI PCI-4351 1-5
NI USB-4350 1-6
Power Considerations 1-6
LED Patterns 1-7
Safety 1-8
Configuring the Hardware in MAX 1-8
Creating a Task in VI Logger 1-9
Using Virtual Channels with VI Logger 1-9
Creating Virtual Channels 1-9
Modifying Virtual Channels 1-9
Testing Virtual Channels 1-10
Creating and Configuring a Task 1-10
Selecting Channels for a VI Logger Task to Acquire and Log Data 1-11
Configuring Events for a Logging Task 1-12
Creating Calculated Channels 1-12
Accessories 1-13

Chapter 2
Operating the NI 435*x* Device

Warming up the NI 435*x* Device 2-1
Choosing a Measurement Mode 2-1
Available Ranges 2-2
Choosing a Reading Rate 2-2
Knowing the Signal Source 2-4
    Floating Signal Source 2-4
    Ground-Referenced Signal Source 2-4
Using Programmable Ground-Referencing 2-5
Using Programmable Open-Thermocouple Detection 2-5
Measuring Temperature with Thermocouples 2-6
    Connecting the Thermocouple 2-8
    Input Ranges 2-8
    Optimizing Measurements 2-8
        Auto Zero 2-9
        Programmable Ground-Referencing 2-9
        Programmable Open-Thermocouple Detection 2-10
        AC Noise Effects 2-10
        Thermal EMF 2-11
Measuring DC Voltage 2-11
    Connecting the DC Voltage Signal 2-11
    Input Ranges 2-11
    Optimizing Measurements 2-12
        Auto Zero 2-12
        Programmable Ground-Referencing 2-12
        Programmable Open-Thermocouple Detection 2-12
        Source Impedance 2-13
        AC Noise Effects 2-13
        Thermal EMF 2-13
Measuring Resistance and Measuring Temperature with RTDs and Thermistors 2-13
    Using the Current Source 2-14
    Connecting Resistors 2-14
    Input Ranges 2-16
    Introduction to RTDs 2-20
        Relationship of Resistance and Temperature in RTDs 2-20
    Connecting the RTD 2-22
    Introduction to Thermistors 2-23
        Resistance-Temperature Characteristic of Thermistors 2-24
    Connecting the Thermistor 2-25

Optimizing Measurements 2-25
Auto Zero 2-25
Programmable Ground-Referencing 2-26
Programmable Open-Thermocouple Detection 2-26
Connecting to External Circuits 2-26
2-Wire, 3-Wire, and 4-Wire Measurements 2-26
Self-Heating 2-27
AC Noise Effects 2-27
Thermal EMF 2-28
Using Digital Inputs and Outputs 2-28
Connecting the Digital Input and Output 2-29

Appendix A
Specifications

Appendix B
Signal Connections

Appendix C
Technical Support and Professional Services

Glossary

Index

About This Manual

This manual describes the National Instruments 4350/4351 devices and contains information concerning device operation and programming.

Conventions

The following conventions appear in this manual:

<> — Angle brackets that contain numbers separated by an ellipsis represent a range of values associated with a bit or signal name—for example, DIO<3..0>.

» — The » symbol leads you through nested menu items and dialog box options to a final action. The sequence **File»Page Setup»Options** directs you to pull down the **File** menu, select the **Page Setup** item, and select **Options** from the last dialog box.

♦ — The ♦ symbol indicates that the following text applies only to a specific product, a specific operating system, or a specific software version.

— This icon denotes a note, which alerts you to important information.

— This icon denotes a caution, which advises you of precautions to take to avoid injury, data loss, or a system crash. When this symbol is marked on the product, refer to the *Read Me First: Safety and Radio-Frequency Interference* document, shipped with the product, for precautions to take.

— This icon denotes a tip, which alerts you to advisory information.

bold — Bold text denotes items that you must select or click in the software, such as menu items and dialog box options. Bold text also denotes parameter names.

italic — Italic text denotes variables, emphasis, a cross reference, or an introduction to a key concept. This font also denotes text that is a placeholder for a word or value that you must supply.

`monospace` — Text in this font denotes text or characters that you should enter from the keyboard, sections of code, programming examples, and syntax examples. This font is also used for the proper names of disk drives, paths, directories, programs, subprograms, subroutines, device names, functions, operations, variables, filenames, and extensions.

NI 435*x*	Refers to all NI 4350 and NI 4351 devices.
NI 435*x* for PXI, PCI, and USB	Refers to the NI 4350 and NI 4351 devices by form factor.
NI PCI-4351	Refers to the NI 4351 for PCI.
NI PXI-4351	Refers to the NI 4351 for PXI.
NI USB-4350	Refers to the NI 4350 for USB. Software sometimes refers to this device as the NI DAQPad-4350.

Related Documentation

This manual is one piece of the NI 435*x* documentation set. Refer to the following documents at `ni.com/manuals` for additional information that is relevant to the NI 435*x* devices.

- *Read Me First: Safety and Radio-Frequency Interference*
- Refer to the following software documentation at **Start»Programs»National Instruments»NI-435x»Documentation**:
  - *NI 435x LabVIEW Reference Help*
  - *NI 435x C/C++/CVI/VB Help*
- Accessory installation guides or manuals—If you are using accessory products, read the terminal block, adapter, and cable assembly installation guides. They explain how to physically connect the relevant pieces of the system. Consult these guides when you are making connections.

Examples

Complete the following steps to refer to the NI 435*x* examples through the NI Example Finder in LabVIEW:

1. Launch LabVIEW.
2. Select **Open**.
3. Select **Examples**.
4. Enter a keyword to search all available examples.

1

Introduction

This chapter describes the NI 435*x* high-precision temperature and voltage meters and describes the optional software and equipment.

About the NI 435*x* High-Precision DAQ Devices

The NI 435*x* devices for PXI, PCI, and USB feature accurate thermocouple and DC voltage meters. You also can take temperature measurements with resistance temperature detectors (RTDs) or thermistors, resistance measurements using built-in precision current sources, and current measurements using external shunt resistors. The NI 435*x* hardware is plug-and-play compatible, fully software calibrated, and compatible with a variety of operating systems.

NI 435*x* hardware has a 24-bit sigma-delta analog-to-digital converter (ADC) with differential analog inputs. The low-leakage construction and analog and digital filtering provide excellent resolution, accuracy, and noise rejection. Software-programmable ground-referencing enables you to reference a floating signal without compromising voltage measurements even if the floating signal is ground-referenced. Software-programmable open-thermocouple detection allows you to detect a broken thermocouple.

You can measure resistance up to 600 kΩ using the built-in 25 µA precision current source on all NI 435*x* hardware, and up to 15 kΩ with the additional built-in 1 mA precision current source on the NI PXI/PCI-4351. Also, programmable TTL-compatible digital I/O (DIO) lines monitor TTL-level inputs, interface with external devices, and generate alarms.

A system based upon NI 435*x* hardware offers flexibility, performance, and compact size, making it ideal for service, repair, and manufacturing, and for use in industrial and laboratory environments.

Detailed specifications for the NI 435*x* devices are in Appendix A, *Specifications*.

Using PXI with CompactPCI

Using PXI-compatible products with standard CompactPCI products is an important feature provided by the PXI Specification. Refer to `www.pxisa.org` for more information.

The NI PXI-4351 does not have connections to reserved lines on the CompactPCI J2 connector. Therefore, you can use the NI PXI-4351 in a CompactPCI system that uses J2 connector lines for purposes other than PXI.

Configuration

The NI 435*x* is a completely software-configurable, plug-and-play instrument. The plug-and-play services query the instrument and allocate the required resources, and the operating system then enables the instrument for operation.

Software Options for the NI 435*x*

You can use LabVIEW, LabWindows™/CVI™, Microsoft Visual Basic, C/C++, or VI Logger to program and use the NI 435*x*. This section provides details on the software choices available for the NI 435*x*.

What Is the NI-435*x* Instrument Driver?

An instrument driver packages instrument capabilities as a set of standard functions. Each function corresponds to a programmatic operation such as configuring, reading from, writing to, and starting and stopping measurements. An instrument driver reduces the program development time and simplifies instrument control by eliminating the need to learn complex programming protocol for each instrument.

The NI-435*x* instrument driver provides programmability in a standard instrument driver format. The instrument driver application programming interface (API) was designed after a traditional, full-featured data logger instrument driver. The NI-435*x* instrument driver is VXI plug-and-play compatible and also contains the source code, so you can examine and modify it. The NI-435*x* instrument driver works with LabVIEW, LabWindows/CVI, or conventional programming languages such as C, C++, and Visual Basic. Refer to the *NI 435x LabVIEW Reference Help* and the *NI 435x C/C++/CVI/VB Help* at **Start»Programs»National Instruments»NI-435x»Documentation**.

What Is LabVIEW?

LabVIEW is a powerful graphical programming language for building instrumentation systems featuring interactive graphics and state-of-the-art user interface. With LabVIEW, you can quickly create front panel user interfaces, giving you interactive control of the software system. To specify the functionality, you intuitively assemble block diagrams—a natural design notation for engineers and scientists. LabVIEW has all of the same development tools and language capabilities of a standard language such as C—looping and Case structures, configuration management tools, and compiled performance.

Use the NI-435*x* instrument driver VIs with LabVIEW.

What Is LabWindows/CVI?

LabWindows/CVI is an interactive ANSI C programming environment designed for automated test applications. LabWindows/CVI enhances traditional programming languages.

Use the NI-435*x* instrument driver functions with LabWindows/CVI.

What Is VI Logger?

VI Logger equips you with the necessary software tools to define and execute a data logging task. With VI Logger, you can view real-time data, share data, and browse and manage historical data. Using VI Logger in Measurement & Automation Explorer (MAX) with such features as event detection and calculated channels, you can define advanced tasks without any programming. Using LabVIEW and the VI Logger VIs, you can execute a task, view live data, browse historical data, and build logging applications using all of the advanced programming capabilities of LabVIEW.

Refer to the *Creating a Task in VI Logger* section of this manual for information on using VI Logger.

Installing the Software

Refer to the *NI 435x Getting Started Guide* that ships with the NI 435*x* hardware or at `ni.com/manuals` for information about installing NI-435*x* instrument driver software and VI Logger software.

Installing the Hardware

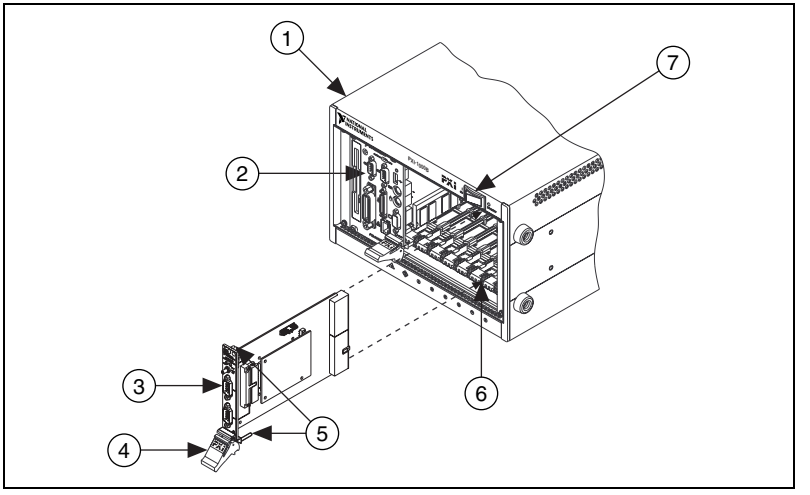
To install the NI PXI-4351, NI PCI-4351, or NI USB-4350 hardware, complete the steps of the appropriate procedure as follows.

Cautions Follow proper ESD precautions to ensure you are grounded before installing the hardware. Refer to Appendix A, *Specifications*, for important safety and compliance information.

For safety information that is relevant to the NI 435*x* devices, refer to the *Read Me First: Safety and Radio-Frequency Interference* document in the NI 435*x* shipping kit or at `ni.com/manuals`.

NI PXI-4351

Complete the following steps and refer to Figure 1-1 to install the NI PXI-4351.



1	PXI Chassis	5	Front-Panel Mounting Screws
2	PXI System Controller	6	Module Guides
3	NI PXI-4351	7	Power Switch
4	Injector/Ejector Handle		

Figure 1-1. Installing the NI PXI-4351

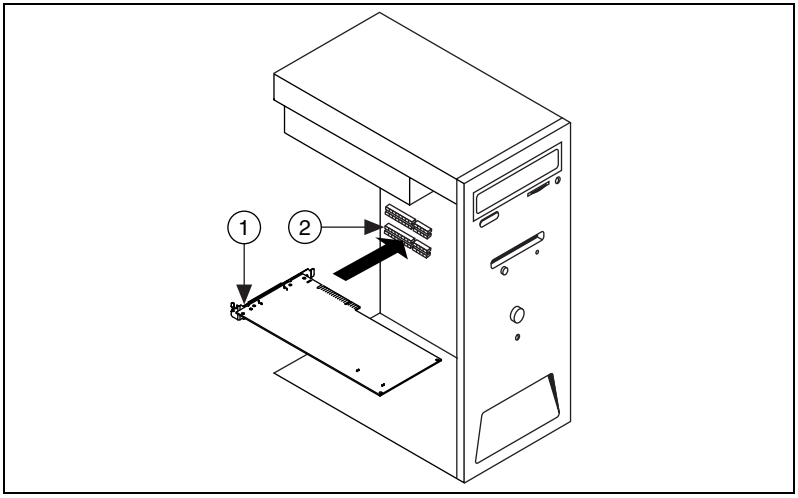
1. Power off and unplug the PXI chassis.

Caution Before removing equipment covers or connecting or disconnecting any signal wires, refer to the *Read Me First: Safety and Radio-Frequency Interference* document in the NI PXI-4351 shipping kit or at `ni.com/manuals`.

2. Remove the filler panel from an unused PXI slot.
3. Touch any metal part of the chassis to discharge static electricity.
4. Ensure that the injector/ejector handle on the NI PXI-4351 is not latched and swings freely.
5. Place the NI PXI-4351 edges into the device guides at the top and bottom of the chassis.
6. Slide the NI PXI-4351 into the PXI slot to the rear of the chassis.
7. When you begin to feel resistance, pull up on the injector/ejector handle to fully insert the NI PXI-4351.
8. Secure the NI PXI-4351 to the chassis front panel mounting rail using the front-panel mounting screws.
9. Plug in and power on the PXI chassis.

NI PCI-4351

Complete the following steps and refer to Figure 1-2 to install the NI PCI-4351:



1	NI PCI-4351	2	PCI Slot

Figure 1-2. Installing the NI PCI-4351

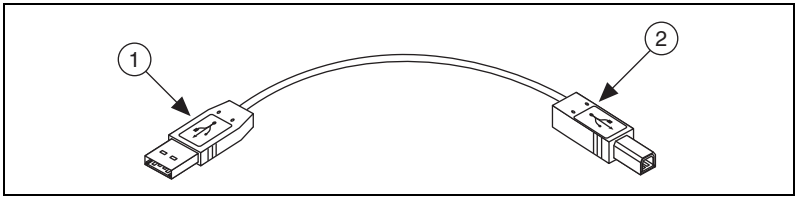
1. Power off and unplug the computer.

Caution Before removing equipment covers or connecting or disconnecting any signal wires, refer to the *Read Me First: Safety and Radio-Frequency Interference* document in the NI PCI-4351 shipping kit or at `ni.com/manuals`.

2. Remove the computer cover and/or the expansion slot cover.
3. Touch any metal part of the computer to discharge static electricity.
4. Insert the device into a PCI slot. Gently rock the device into place. Do *not* force the NI PCI-4351 into place.
5. Secure the device mounting bracket to the computer back panel rail.
6. Replace the computer cover, if applicable.
7. Plug in and power on the computer.

NI USB-4350

To install the NI USB-4350, connect the cable from the computer USB port to an available USB port on the NI USB-4350. Figure 1-3 shows the USB cable and its connectors.



1 Connector to the Computer or USB Hub 2 Connector to the NI USB-4350

Figure 1-3. USB Cable and Connectors

When you connect the NI USB-4350 to the PC, the computer recognizes the NI USB-4350 immediately, and the LED on the device front panel blinks or lights up, depending upon the status of the NI USB-4350.

Power Considerations

The NI USB-4350 is powered on only when the USB cable connects the NI USB-4350 to the host PC, and the PC is powered on. The NI USB-4350 is designed to run in a stand-alone mode, drawing power only from the USB cable. At times, the NI USB-4350 may require more power than the USB power supply can safely deliver. If the NI USB-4350 tries to draw more than the allowed current from the USB power supply, internal protection circuitry turns off most of the circuitry in the NI USB-4350 to

protect the USB power supply. This over-current condition makes the LED blink in the power supply overload pattern described in the *LED Patterns* section.

Note When the NI USB-4350 powers off, any data acquisition in progress is aborted and the data is lost.

The host computer has the ability to go into a power-saving suspend mode and, during this time, the NI USB-4350 also can either go into a low-power mode or remain in a fully-powered, static state. This low-power mode is important if you are using a laptop or if power consumption is a concern.

In the powered, static state of the NI USB-4350, all digital outputs are static at a fixed voltage.

Note By default, the NI USB-4350 remains fully powered during suspend mode. To change the settings that determine the behavior of the NI USB-4350 during suspend mode, refer to one of the following locations:

- The *Set_DAQ_Device_Info* section of the *Traditional NI-DAQ (Legacy) Function Reference Help*, located at **Start»Programs»National Instruments»NI-DAQ» Traditional NI-DAQ (Legacy) Function Reference Help**.
- The *Set DAQ Device Information (Device Setting VI)* section of the *LabVIEW Help*, located at Start**»Programs»National Instruments»LabVIEW 7.*x*»VI, Function, & How-To Help**.

LED Patterns

If the LED comes on after the NI USB-4350 is connected to the computer, the device is functioning properly. If the LED remains off or blinks, refer to Table 1-1.

Table 1-1. LED State Patterns for the NI USB-4350 States[1]

LED	State	Description
On	Configured state	The NI USB-4350 is configured.
Off	Off or in the low-power, suspend mode	The NI USB-4350 is powered off or is in the low-power, suspend mode.
1 blink	Attached state	The NI USB-4350 is recognized but not configured.
2 blinks	Addressed state	The host computer detects the NI USB-4350 but cannot configure it, because the device driver is improperly installed or system resources are unavailable. Check the software installation.

Table 1-1. LED State Patterns for the NI USB-4350 States[1] (Continued)

LED	State	Description
3 blinks	Power supply failure	The internal power supply shut down. Refer to the *Power Considerations* section for more information.
4 blinks	General error state	Contact NI. Refer to Appendix C, *Technical Support and Professional Services*, for contact information.

[1] The LED blinks in one-second intervals during each cycle. The LED then waits three seconds before repeating the cycle.

Safety

For safety information that is relevant to the NI 435*x* devices, refer to the *Read Me First: Safety and Radio-Frequency Interference* document in the NI 435*x* shipping kit or at `ni.com/manuals`.

Configuring the Hardware in MAX

To configure the NI 435*x* hardware in MAX, complete the following steps:

1. Double-click the **Measurement & Automation** icon on the desktop to open MAX.
2. Expand **Devices and Interfaces**.
3. Expand **Traditional NI-DAQ (Legacy) Devices**.
4. Verify that the NI 435*x* device name appears under Traditional NI-DAQ (Legacy) Devices.
5. If the NI 435*x* device name does not appear, press **<F5>** to refresh the view in MAX. If the device is still not recognized, refer to `ni.com/support/install` for troubleshooting information.
6. Right-click the NI 435*x* device name and select **Properties** to open the Configuring Device window. Configure the device properties, including accessories in the Accessory tab.
7. Click **Apply** to accept the changes.
8. Click **Test Resources** in the System tab of the Configuring Device window.
9. When the self-test finishes, a message indicates successful verification or if an error occurred. If an error occurs, refer to `ni.com/support/install` for troubleshooting information.
10. Click **OK** to close the Configuring Device window.

Creating a Task in VI Logger

This section explains how to configure and run a task using VI Logger with the NI 435*x* hardware and how to view or export the resulting data.

Caution To use VI Logger with the NI 435*x* devices, you must activate VI Logger. Refer to `ni.com/license` to activate VI Logger.

Before you create a VI Logger task, you should confirm that you have properly configured the NI 435*x* hardware and associated accessories (if applicable) as outlined in *Configuring the Hardware in MAX*.

Using Virtual Channels with VI Logger

Before you create a VI Logger task for an NI-DAQ traditional virtual channel, you need to first create the virtual channel and test it.

Creating Virtual Channels

Complete the following steps to create the traditional virtual channels to use in a data logging task.

1. Launch the **Measurement & Automation** icon.
2. In the MAX configuration tree, right-click **Data Neighborhood** and select Create New from the pop-up menu.
3. The **Create New** wizard opens. Select **Traditional NI-DAQ (Legacy) Virtual Channel** and follow the wizard instructions to create a new virtual channel.

Modifying Virtual Channels

Complete the following steps to modify a virtual channel.

1. In the configuration tree of MAX, right-click a virtual channel under **Data Neighborhood**.
2. Select **Properties**.
3. Make any modifications necessary in the **Configuration** dialog box that appears.
4. Click **OK** when you are finished.

Note Click the **Advanced...** button to view and change additional channel properties, including Auto-zero Mode, Notch Filter Frequency, Open Thermocouple Detection, and Ground Referencing.

Testing Virtual Channels

The Virtual Channel Test Panels show actual readings so you can directly control the different channels you have configured. Complete the following steps to test the virtual channels.

1. In the configuration tree of MAX, right-click a virtual channel under **Data Neighborhood**.
2. Select **Test**.
3. View the readings and change any parameters in the **Virtual Channel Test Panels** dialog box.
4. Click **Close** when you are finished.

Creating and Configuring a Task

When you configure a logging task, VI Logger provides feedback if any choices you make are invalid. Complete the following steps to create a data logging task.

1. Launch VI Logger by selecting **Start»Programs»National Instruments»VI Logger»VI Logger in MAX**.
2. In the configuration tree in MAX, right-click **VI Logger Tasks** and select **Create New**. The **Create New** dialog box appears.
3. Select **Using Traditional NI-DAQ (Legacy)** and click **Finish**. In the MAX configuration tree, the newly created task is selected and the **Task Attributes** view is selected.

Note If you can only use NI-DAQmx rather than Traditional NI-DAQ (Legacy), you must still activate the VI Logger license. Refer to `ni.com/license` for more information.

   VI Logger automatically gives the task a unique default name, which appears under VI Logger Tasks. You can rename the task by right-clicking on the task name and selecting **Rename Task**.

4. In the **Acquisition Settings** section, enter the following fields:
   a. In the **Device** field, select the device you are using.
   b. Select **Filter Frequency**. Refer to Table 2-1, *Filtering and Sample Rates*, to determine the reading rate.
5. In the **Buffer Settings** section, you can define buffering parameters for the task. With these parameters, you can modify the performance of VI Logger, specifically if you are trying to log data at a high rate.

Tip You cannot log data from more than one NI-DAQ device per task. However, you can define one task for each device and can run more than one task at the same time.

6. In the **Logging Conditions** section, you can control datalogging using one of the digital lines. Refer to the *Using Digital Lines to Control Datalogging* section of the *VI Logger Help* by selecting **Help» Help Topics»VI Logger»VI Logger** in MAX.

Note The NI 435*x* hardware does *not* support digital or analog triggering. By default, the **Start acquisition on trigger** checkbox is unchecked. If you select the checkbox, you receive an error when you start the task; this error indicates that triggering is not supported. Refer to step 6 above for alternative software triggering.

Selecting Channels for a VI Logger Task to Acquire and Log Data

For each VI Logger task you configure, you can select which specific channels acquire and log data within that task.

Complete the following steps to set up the channels that acquire and log data.

1. With a VI Logger Task selected, click the **Virtual Channels** tab to open the Virtual Channels view.
2. Right-click the **Events** column heading and select **Events** to enable or disable the information displayed in the table. Refer to the Measurement & Automation Explorer Help for VI Logger by selecting **Help»Help Topics»VI Logger»VI Logger** for more information about the information columns in the Virtual Channels view.
3. The **Active Channel** column displays all the virtual channels you have created in MAX for your device. To enable logging for each channel, place a checkmark in the **Log Enabled?** checkbox to the right of each channel name.

Tip To add a virtual channel, click **Create channel** and follow the instructions in the Create New Channel wizard.

Refer to the *Creating Calculated Channels* section for information about creating calculated channels for VI Logger tasks.

Configuring Events for a Logging Task

You can configure events to be logged in your task that will appear in the Events view. Complete the following steps to configure the events for a logging task.

1. In the NI-DAQ Channels view, right-click the **Channels** column and select **Events**.
2. Check and uncheck the desired events to select which events to display for the channels.
3. You also can right-click the table cells to access more options to modify these conditions.

Creating Calculated Channels

You can set up mathematical equations that use virtual channels using math channels. For example, for channels **Channel 0** and **Channel 1**, you could enter the equation `Channel 0 - Channel 1`, to subtract one from the other. The result would be a calculated channel.

Complete the following steps to create a calculated channel.

1. Click the **Calculated Channels** tab to display the **Calculated Channels** view.
2. Click **Create channel**. The **Math Expression Editor** dialog box appears where you can define a math channel.
3. In the **Channel Settings** section in the **Name** field, enter an appropriate name for the math channel.
4. In the **Units** field, enter the appropriate unit type.
5. In the **Minimum** and **Maximum** fields, enter a range of units that applies to the math channel.
6. In the **Formula Settings** section in the **Formula** field, click the down arrow, and select one of four formulas to apply to the math channel:
   - **Ax (Op) By + C**—A linear combination formula. Fill in fields **A**, **Channel X**, **Operation**, **B**, **Channel Y**, and **C** with the appropriate values.
   - **db x/y**—A measurement of noise (db)–power base 10. Select the channels you want for **Channel X** and **Channel Y** fields.
   - **dBVx**—A single channel noise measurement. Select the channel you want for the **Channel X** field.
   - **User Defined**—A formula that you create.
7. Click **OK**.

Accessories

NI offers a variety of products to use with the NI 435*x*, including cables, connector blocks, terminal blocks, and other accessories, as follows:

- Isothermal terminal blocks—TBX-68T, CB-68T, and TC-2190
- Terminal blocks—TBX-68
- Shielded and ribbon cables

For more information about these products, contact NI or search for `NI PXI-4351`, `NI PCI-4351`, or `NI USB-4350` at `ni.com/catalog`.

2

Operating the NI 435*x* Device

This chapter describes how to use the NI 435*x* device and includes operation tips on taking measurements with temperature sensors such as thermocouples, RTDs, and thermistors, as well as measuring voltages and resistances.

Caution Refer to the *Read Me First: Safety and Radio-Frequency Interference* document before removing equipment covers or connecting/disconnecting any signal wires.

Warming up the NI 435*x* Device

To minimize the effects of thermal drift and to ensure the specified accuracy, allow the NI 435*x* device to warm up for at least 10 minutes after startup before taking measurements. To maximize the relative accuracy of measurements, take all measurements after the NI 435*x* device warms up for 30 minutes.

Choosing a Measurement Mode

You can configure the analog input channels for measuring outputs of various transducers, as follows:

- Voltage
- Thermocouples
- Resistors
- RTDs

Note When you are using Traditional NI-DAQ (Legacy) virtual channels in VI Logger, the measurement mode is chosen by the specified sensor type.

Available Ranges

The volts mode has six bipolar input ranges: ±625 mV, ±1.25 V, ±2.5 V, ±3.75 V, ±7.5 V, and ±15 V.

The resistance mode has six corresponding input ranges when used with the built-in 25 µA current source on the NI PXI-4351, NI PCI-4351, and NI USB-4350: 25 kΩ, 50 kΩ, 100 kΩ, 150 kΩ, 300 kΩ, and 600 kΩ. With the additional built-in 1 mA current source on the NI PXI-4351 or NI PCI-4351, resistance mode also has 625 Ω, 1.2 kΩ, 3.75 kΩ, 7.5 kΩ, and 15 kΩ as possible input ranges.

For the best measurement results, specify the upper and lower limit values of the measurement when configuring the NI 435*x*. When scanning multiple channels, the NI 435*x* uses a single range, which is the widest range of any channel in the scan list.

Note Specify the limit values in engineering units appropriate to the sensor. This sensor range is used to automatically set the actual hardware range.

Choosing a Reading Rate

The reading rate is the rate at which the NI 435*x* takes a new measurement. This rate has a direct relationship with the digital filter built into the ADC on the NI 435*x*.

The digital filter has the characteristics shown in Figure 2-1. You can set the frequency of the first notch of this filter to 10 Hz, 50 Hz, or 60 Hz. Setting the notch filter at one of these frequencies rejects any noise at that frequency as well as at all of its multiples.

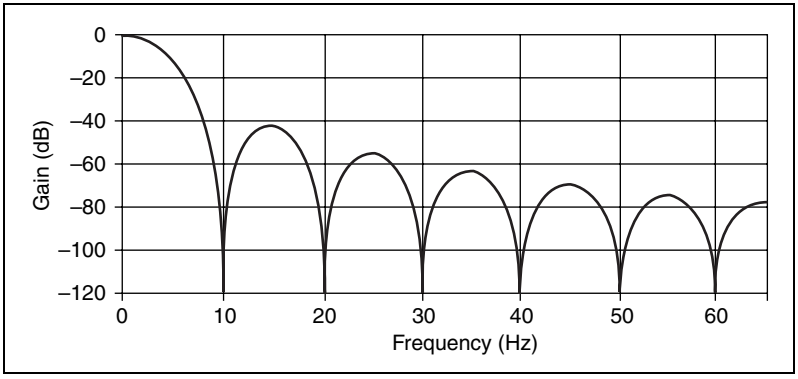


Figure 2-1. Digital Filter Characteristics for 10 Hz Setting

In single-channel measurements, the reading rate is the same as the notch filter frequency—10, 50, or 60 readings/s. In multiple-channel measurements, the reading rates adjust to allow the analog and digital filters to settle to the specified accuracy.

Note To determine the reading rate per channel when scanning multiple channels, divide the multiple-channel measurement reading rate in Table 2-1 by the number of channels in the scan.

In certain applications, such as resistance measurements above 25 kΩ or voltage measurements with more than 25 kΩ of source resistance, you should measure the same channel for up to 1 s, then switch to another channel to achieve the specified accuracy. This extra time allows the input filter capacitors of the NI 435*x* devices to fully charge or discharge.

To optimize measurement accuracy and minimize the noise level, choose the 10 Hz notch filter setting.

In practice, most of the noise encountered in measurements occurs at harmonics (multiples) of the local powerline frequency (PLF). Table 2-1 shows which filter settings reject harmonics of particular frequencies.

Table 2-1. Filtering and Sample Rates

NI-DAQ	NI-435*x*		Equivalent Filter Setting		Harmonics of Noise Frequencies Rejected (Hz)	Single-Channel Measurement Reading Rate (readings/s)	Multiple-Channel Measurement Reading Rate ‡ (readings/s)	
Notch Filter Frequency Setting (Hz)	PLF* (Hz)	Reading Rate	PLC†	PLF* (Hz)				
10	50 or 60	slow	5 6 40	50 60 400	10, 50, 60, and 400	10	2.8	1.4**
50	50	fast	1 8	50 400	50 and 400	50	8.8	2.1**
60	60	fast	1	60	60	60	9.7	2.1**

* Powerline frequency.
† Number of powerline cycles used for filtering.
‡ To determine the reading rate per channel, divide this value by the number of channels in the scan.
** For resistance ranges of 50 kΩ and higher.

Note These rates were obtained without Auto Zeroing and cold-junction compensation.

Knowing the Signal Source

For accurate measurements, you must determine whether the signal source is floating or ground-referenced.

Floating Signal Source

A floating signal source is one that is not connected in any way to the building ground system but has an isolated ground-reference point. Examples of floating signal sources are thermocouples with ungrounded junctions and outputs of transformers, batteries, battery-powered devices, optical isolators, and isolation amplifiers.

Ground-Referenced Signal Source

A ground-referenced signal source is one that is connected in some way to the building system ground. Therefore, it is already connected to a common ground point with respect to the NI 435*x*, assuming that the computer is plugged into the same power system. Examples of ground-referenced signal sources include the following:

- Thermocouples with grounded or exposed junctions connected to grounded test points

- The outputs of plug-in devices with nonisolated outputs
- Voltage across RTDs, thermistors, or resistors that you may be measuring using the built-in current sources of the NI 435*x*

Using Programmable Ground-Referencing

The NI 435*x* devices have software-programmable ground-referencing on every channel, which you can use to ground-reference a floating signal source. This connects CH– to ground through a 10 MΩ resistor and provides a ground-reference for the floating signal source. Even if the signal source is ground-referenced, this resistance minimizes the effects of ground-loops, as long as the source impedance and the lead wire resistance is less than 100 Ω. Thus, you can take accurate measurements even if you are uncertain whether the signal source is floating or ground-referenced.

Because you can set ground-referencing on a channel-by-channel basis, you can have ground-referenced signal sources connected to some channels and floating signal sources connected to other channels in the same measurement setup. Table 2-2 summarizes the settings to use for ground-referencing.

Table 2-2. Using Programmable Ground-Referencing

Signal Source	Programmable Ground-Referencing
Floating	On
Ground-referenced	Off

Note Programmable ground-referencing applies to voltage and thermocouple modes only.

Using Programmable Open-Thermocouple Detection

The NI 435*x* devices have software-programmable, open-thermocouple detection on every channel, which you can use to detect an open or broken thermocouple. This feature connects CH+ to +2.5 V through a 10 MΩ resistor. This resistor acts as a pull-up resistor and, consequently, the voltage between CH+ and CH– rises rapidly above 100 mV if the thermocouple breaks open. All thermocouples functioning under normal conditions generate a voltage of less than 100 mV, even at very high temperatures. You can detect this voltage level in software and conclude that the thermocouple is open.

To understand how setting open-thermocouple detection affects the accuracy of measurements, refer to the *Programmable Open-Thermocouple Detection* section. You can set open-thermocouple detection on a channel-by-channel basis. Table 2-3 summarizes the settings you should use for open-thermocouple detection.

Table 2-3. Using Programmable, Open-Thermocouple Detection

Signal Source	Programmable Open-Thermocouple Detection
Thermocouples	On or Off
Voltage signal sources other than thermocouples	Off
RTDs, thermistors, and resistors connected to the built-in current source	Off

Note The default setting for programmable open-thermocouple detection in volts and 4-wire ohms measurement modes is Off.

Measuring Temperature with Thermocouples

A thermocouple, which measures temperature, operates on the principle that the junction of two dissimilar metals generates a voltage that varies with temperature, or thermal electromotive force (EMF). However, just measuring this voltage is not sufficient because connecting the thermocouple to the NI 435*x* accessory creates the reference junction, or cold-junction, shown in Figure 2-2. These additional junctions act as thermocouples and produce their own voltages. Thus, the final measured voltage, $V_{measured}$, includes both the thermocouple voltage, $V_{thermocouple}$, and the cold-junction voltage, $V_{cold\text{-}junction}$. The method of compensating for these unwanted cold-junction voltages is called cold-junction compensation (CJC).

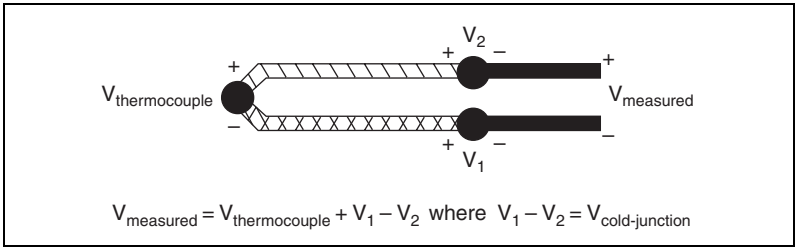


Figure 2-2. Effect of the Cold-Junction

With the NI 435*x*, you can perform CJC in software in three ways, as follows:

- Using the built-in thermistor temperature sensor on an NI 435*x* accessory to measure the ambient temperature at the cold junction and compute the appropriate compensation for the unwanted thermoelectric voltages using software. The cold-junction sensor is on analog channel 0 on the TC-2190, TBX-68T, and CB-68T accessories.

  If you are using NI-435*x* and have configured the accessory in MAX, use thermocouple mode with the CJC setting of Auto to enable the software to perform cold-junction compensation on all configured thermocouple channels.

  If you are using VI Logger and have configured the accessory in MAX, use the Built-In option for the CJC source on the Traditional NI-DAQ (Legacy) virtual channel.

- Providing a constant user value.

  If you are using NI-435*x*, use the CJC setting of Manual on the configured thermocouple channel.

  If you are using VI Logger, use and specify the User-Value option for the CJC source on the Traditional NI-DAQ (Legacy) virtual channel.

- Providing your own temperature sensor for CJC, in which case you must complete all measurement acquisition and computational steps. For example, if you are using a thermistor as a CJC sensor, you must complete the following steps:

  1. Measure the resistance of the thermistor cold-junction sensor, $R_{\text{thermistor cold-junction}}$, and compute the cold-junction temperature, $T_{\text{cold-junction}}$, using the thermistor resistance-temperature conversion formula.
  2. From this temperature of the cold-junction, $T_{\text{cold-junction}}$, compute the equivalent thermocouple voltage, $V_{\text{cold-junction}}$, for this junction using a standard thermocouple conversion formula.

3. Measure the voltage, $V_{measured}$, and add the cold-junction voltage, $V_{cold\text{-}junction}$, computed in step 2.
4. Convert the resulting voltage to temperature using a standard thermocouple conversion formula.
5. Use the CJC setting of Manual on the configured thermocouple channel.

Connecting the Thermocouple

The NI 435*x* accessories—the TC-2190, TBX-68T, and CB-68T for the NI 435*x* for PXI, PCI, and USB—are designed to be used with thermocouples. Consult the accessory installation guide for instructions on how to connect the thermocouples. To make accurate measurements, make sure that the common-mode voltage of the thermocouple is within the common-mode limits of the selected input range.

Caution To prevent possible safety hazards, the maximum voltage between any of the analog inputs and the computer ground should *never* exceed ±42 VDC when the NI 435*x* is powered on and ±17 VDC when the NI 435*x* is powered off.

The NI 435*x* analog inputs are protected against damage from voltages within ±42 VDC in all ranges when powered on and ±17 VDC when the NI 435*x* device is powered off. Never apply voltages above these levels to the inputs.

Input Ranges

Choose the ±625 mV range in volts mode when you are measuring thermocouples. You can measure both the thermocouples and the thermistor cold-junction sensor on the NI 435*x* accessory in the same scan by choosing the 25 kΩ range for measuring the thermistor. These ranges offer the best resolution, noise rejection, and accuracy.

Note If scanning thermocouples and other transducers, the NI 453*x* device uses the widest range for all channels, which can make the thermocouple measurements appear noisier.

Optimizing Measurements

To make accurate thermocouple measurements, set the onboard programmable ground-referencing and open-thermocouple detection appropriately. Also consider problems associated with AC noise effects, thermal EMF, and other errors as discussed in the following sections.

Auto Zero

Auto Zero removes any offset errors in the measurement. Analog channel 1 (CH1) on the TC-2190, TBX-68T, and CB-68T is dedicated for Auto Zero. CH1+ is connected to CH1– on these accessories. You can measure the voltage offset on this Auto Zero channel and subtract it from the voltage measurements on other channels. Hence, you can compensate for any residual offset error the NI 435*x* may have. This compensation is especially useful when the NI 435*x* device is operating at an ambient temperature other than that of calibration (23 °C typical).

Note When measuring the transducer channel with Auto Zero and/or cold-junction compensation, the NI 435*x* device operates at its multi-channel rate. Refer to Table 2-1 for this rate.

Programmable Ground-Referencing

If you determine that the thermocouple is ground-referenced, switch off ground-referencing on that channel.

If you determine that the thermocouple is floating, switch on ground-referencing on that channel. Otherwise, the thermocouple inputs may float out of the input common-mode limits of the NI 435*x* device.

On all the NI 435*x* accessories used with thermocouples, analog channel CH0 is dedicated to the thermistor cold-junction sensor. The built-in current source return terminal I_{EX-} or I_{EX0-} is tied to –2.5 V through a resistor. This –2.5 V references any resistor excited by the current source to ground. Since this current source excites the cold-junction thermistor, CH0 is automatically ground-referenced. Therefore, when measuring the voltage across this thermistor, always switch off programmable ground-referencing on CH0. Otherwise, the leakage current flowing into the thermistor may cause erroneous measurements in all the channels that use the current source. Current source terminal I_{EX1-} also is tied to –2.5 V through a resistor.

Note When using VI Logger in MAX with Traditional NI-DAQ (Legacy) virtual channels, the ground-referencing switch on the cold-junction sensor channel and Auto Zero channel is automatically set appropriately.

Programmable Open-Thermocouple Detection

To detect open or broken thermocouples, switch on open-thermocouple detection on that channel. Then, if the thermocouple breaks, the voltage on that channel rises rapidly above 100 mV, at which point you can conclude that the thermocouple is open.

Notice that when open-thermocouple detection is on and the floating thermocouple is not broken, a very small amount of current is injected into the thermocouple. The value of the current is approximately 125 nA when ground-referencing also is on. If the thermocouple is very long, the injected current can cause an error voltage to develop in the lead resistance of the thermocouple that is indistinguishable from the thermocouple voltage you are measuring. You can estimate this error voltage with the following formula:

$$\text{error voltage} = \text{resistance of thermocouple} \times 125\ \text{nA}$$

For example, if you use a 100 ft long, 24 AWG J-type thermocouple with a resistance of 0.878 Ω per double foot, the error voltage generated is approximately 11 µV, which corresponds to about 0.2 °C. If this error is too large for the measurement, you can reduce the error by reducing the thermocouple resistance or by lowering the length of the thermocouple or gauge of the wire (use a wire of larger diameter). Alternatively, you can switch off the open-thermocouple detection to eliminate the current injected into the thermocouple.

AC Noise Effects

The NI 435*x* rejects AC voltages as specified in normal-mode rejection (NMR) in Appendix A, *Specifications*. However, if the amplitudes of the AC voltages are large compared to the DC voltages, or if the peak value (AC plus DC) of the measured voltage is outside the input range, the NI 435*x* may exhibit additional errors. To minimize these errors, keep the thermocouples, the NI 435*x*, and its accessories away from strong AC magnetic sources, and minimize the area of the loop formed by the thermocouple wires connected to the accessory. Choose the notch filter frequency of 10 Hz for the best AC noise rejection. If the peak value of the measured voltage is likely to exceed the selected input range, select the next higher input range.

Thermal EMF

When using thermocouples, any thermal EMFs introduce error other than those at the hot junction (where the thermocouple measures the test point temperature) and at the cold junction on the accessory.

To minimize thermal EMFs, use wires made of the same material as the thermocouple when extending the length of the thermocouple. Also, minimize temperature gradients in the space enclosing the thermocouples, the NI 435*x*, and its accessories.

Measuring DC Voltage

Connecting the DC Voltage Signal

The NI 435*x* accessories—the TBX-68T, CB-68T, TBX-68, and TC-2190 for the NI 435*x* for PXI, PCI, and USB—are designed to be used with any DC voltage signal. Consult the accessory installation guide for instructions on how to connect the voltage signals.

The NI 435*x* analog inputs are protected against damage from voltages within ±42 VDC in all ranges when powered on and ±17 VDC when the NI 435*x* is powered off. Never apply voltages above these levels to the inputs.

Caution To prevent possible safety hazards, the maximum voltage between any of the analog inputs and the computer ground should *never* exceed ±42 VDC when the NI 435*x* is powered on and ±17 VDC when the NI 435*x* is powered off.

Input Ranges

The NI 435*x* has six bipolar input ranges available for measuring DC voltage. These ranges are ±625 mV, ±1.25 V, ±2.5 V, ±3.75 V, ±7.5 V, and ±15 V. The NI 435*x* can measure DC voltage to the specified accuracy as long as the voltage is within the selected input range. To get the best resolution, noise rejection, and accuracy, choose the smallest possible range. Make sure that each signal input to CH+ and CH– is within the common-mode limits of this input range. The input common-mode limits are ±2.5 V and ±15 V for the lower three and higher three input ranges, respectively.

Note If scanning voltages in different ranges, the NI 435*x* uses the widest voltage range for all channels, which can make the lower voltage signal measurements appear noisier.

Optimizing Measurements

To make accurate voltage measurements, program the onboard ground-referencing and open-thermocouple detection appropriately. Also consider problems associated with AC noise effects, thermal EMFs, and other errors as discussed in the following sections.

Auto Zero

Auto Zero removes any offset errors in the measurement. Analog channel 1 (CH1) on the TBX-68T, TC-2190, and CB-68T is dedicated for Auto Zero. CH1+ is connected to CH1– on these accessories. When using a TBX-68 accessory, connect CH– to CH+ (any channel) to make that channel useful for Auto Zero. You can measure the voltage offset on this Auto Zero channel and subtract it from the voltage measurements on other channels. This way, you can compensate for any residual offset error the NI 435*x* may have. This compensation is especially useful when the NI 435*x* is operating at an ambient temperature other than that of calibration (23 °C typical).

Note When measuring the transducer channel with Auto Zero, the NI 435*x* operates at its multi-channel rate. Refer to Table 2-1 for this rate.

Programmable Ground-Referencing

If you determine that the signal source is ground-referenced, switch off ground-referencing on that channel.

If you determine that the signal source is floating, switch on ground-referencing on that channel. Otherwise, the inputs may float out of the input common-mode limits of the NI 435*x*.

When you use the TBX-68T and CB-68T accessories, always switch on ground-referencing on CH1. Doing this ground-references the Auto Zero channel.

Note When using VI Logger in MAX with Traditional NI-DAQ (Legacy) virtual channels with the accessories, including the CB-68T, TC-2190, or TBX-68T, the ground-referencing switch on the Auto Zero channel is automatically set appropriately.

Programmable Open-Thermocouple Detection

When you measure voltage signals other than thermocouples, always switch off the onboard open-thermocouple detection.

Source Impedance

For best results, maintain the source impedance and the lead wire resistance of the signal at less than 100 Ω. If either of these is greater than 25 kΩ, you should measure the same channel for up to 1 s, then switch to another channel to achieve the specified accuracy.

AC Noise Effects

The NI 435*x* rejects AC voltages as specified in Appendix A, *Specifications*. However, if the amplitudes of the AC voltages are large compared to the DC voltages, or if the peak value (AC plus DC) of the measured voltage is outside the input range, the NI 435*x* may exhibit additional errors. To minimize these errors, keep the signal source, the NI 435*x*, and its accessories away from strong AC magnetic sources, and minimize the area of the loop formed by the wires that connect the signal source with the accessories. Choosing the notch filter frequency of 10 Hz provides the best AC noise rejection. If the peak value of the measured voltage is likely to exceed the selected input range, select the next higher input range.

Thermal EMF

Thermoelectric potentials or thermal EMFs are voltages generated at the junctions of dissimilar metals and are functions of temperature. Thermal EMFs in the source generating the signal can introduce errors in measurements that change with variations in temperature.

To minimize thermal EMFs, use copper wires to connect the signal to the NI 435*x* accessory. Avoid using dissimilar metal wires in connections. Also, minimize temperature gradients in the space enclosing the signal source, the NI 435*x*, and its accessories.

Measuring Resistance and Measuring Temperature with RTDs and Thermistors

RTDs and thermistors are essentially resistors whose resistance varies with temperature. Therefore, measurement techniques for RTDs, thermistors, and resistors are quite similar. All techniques involve exciting the resistor with a current or a voltage source and measuring the resulting voltage or current, respectively, developed in the resistor.

The NI 435*x* accessories—the TBX-68T, CB-68T, and TBX-68 for the NI 435*x* for PXI, PCI, and USB—are designed to be used with RTDs,

thermistors, and resistors. Consult the accessory installation guide for instructions on how to configure the terminal block.

Using the Current Source

The NI PXI-4351, NI PCI-4351, and NI USB-4350 feature a 25 µA precision current source, which supplies excitation for a total maximum load resistance of 600 kΩ. The NI PXI/PCI-4351 has an additional precision current source, which supplies 1 mA excitation for a total maximum load resistance of 15 kΩ.

These resistances can be in the form of RTDs, thermistors, or any other resistor. The calibrated value of the current source is stored onboard, and NI-435*x* uses this precise value in its computations.

Connecting Resistors

To measure resistance, you must pass current through the device and measure the resulting voltage. NI-435*x* returns resistance measurements by dividing the measured voltage by the calibrated value of the current source stored onboard. However, any resistance in the lead wires that connect the measurement system to the resistor adds errors to the readings.

Figure 2-3 shows an example of an RTD connected to the NI 435*x* accessory using two leads. The NI 435*x* accessory also supplies a constant current source, $I_{EX,}$ to excite the resistor. This type of connection is known as a 2-wire connection. The voltage measured corresponds to the voltage drops across the resistor under test and across the two lead resistances, R_L.

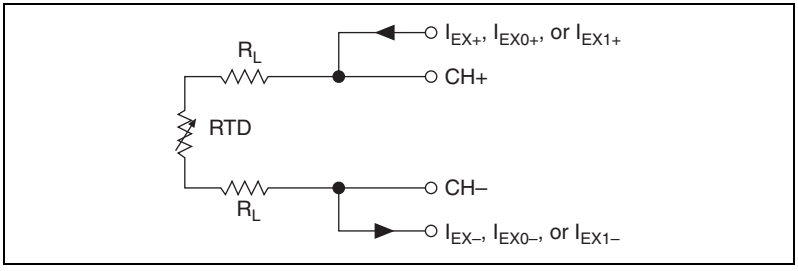


Figure 2-3. 2-Wire Measurement, where an RTD is the Resistor Under Test

For example, a lead resistance R_L of 0.3 Ω in each wire adds a 0.6 Ω error to the resistance measurement.

If you are using lead lengths greater than 10 ft, you may need to compensate for this error. To compensate for lead resistance, the preferred

measurement method is to use a 4-wire connection, where one pair of wires carries the excitation current and the other pair of wires senses the voltage across the resistor. Because the input impedance of the channel (CH+ and CH–) is very high, practically no current flows through the sensing wires, the lead resistance error of R_{L2} and R_{L3} is negligible. Figure 2-4 illustrates this configuration.

Note To minimize the error due to lead resistance, connect the voltage sense terminals (CH+ and CH–) as close as possible to the resistor under test.

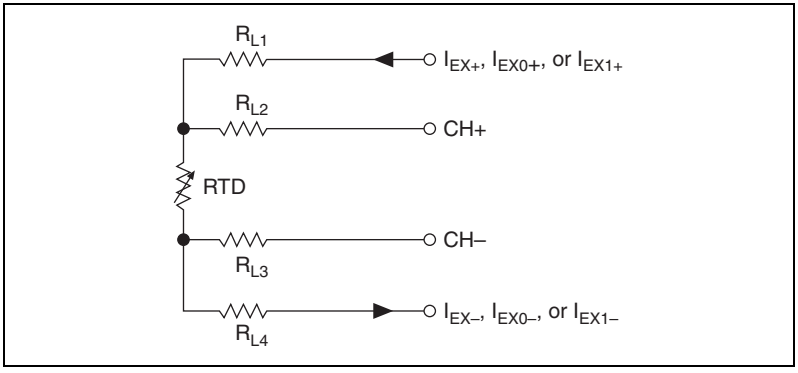


Figure 2-4. 4-Wire Measurement, where an RTD is the Resistor Under Test

Alternatively, you can use a 3-wire connection. Figure 2-5 shows a 3-wire resistor configuration with a current source. In this configuration, the resistance of only one lead, R_{L1}, adds error to the measurement.

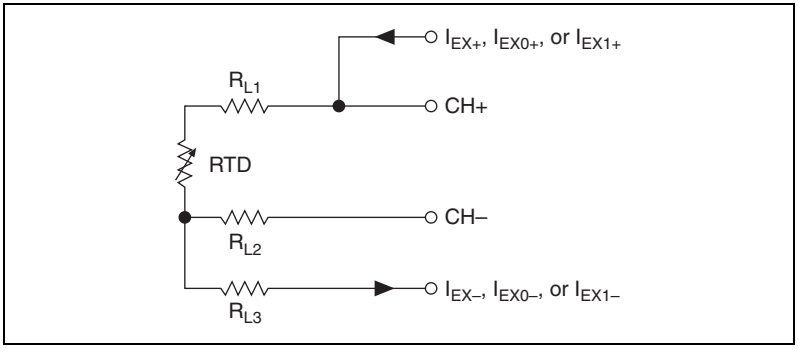


Figure 2-5. 3-Wire Measurement, where an RTD is the Resistor Under Test

Another variation of the 3-wire configuration is shown in Figure 2-6. In this configuration, the effects of the same lead resistance cancel out as long as

all three wires have the same lead resistance. However, it uses two input channels per resistor while the previous configurations use only one.

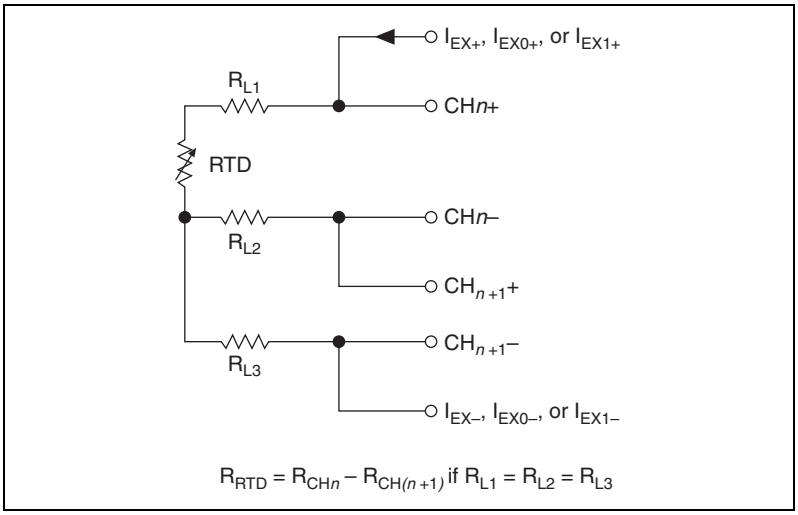


Figure 2-6. 3-Wire Measurement and Lead Wire Resistance Compensation, where an RTD is the Resistor Under Test

Note For best results, use the 1 mA current source when using the NI 4351 with RTDs or resistors with resistances below 1 kΩ. For resistances above 1 kΩ or with the NI 4350, use the 25 µA current source to avoid self-heating. Refer to the *Self-Heating* section for further details.

You can use the same current excitation for several resistors as long as you do not exceed the maximum load and are within the common-mode voltage specification listed in Appendix A, *Specifications*. Refer to Figures 2-7 and 2-8 for examples of how you can use different transducers connected to analog channels in the same measurement setup.

Input Ranges

With the 25 µA current source, the NI PXI-4351, NI PCI-4351, and NI USB-4350 have six ranges for resistance measurements: 25 kΩ, 50 kΩ, 100 kΩ, 150 kΩ, 300 kΩ, and 600 kΩ. These ranges correspond to the six input ranges available for measuring DC voltages developed across resistors: ±625 mV, ±1.25 V, ±2.5 V, ±3.75 V, ±7.5 V, and ±15 V. The NI PXI/PCI-4351 has six additional ranges of 625 Ω, 1.25 kΩ, 2.5 kΩ, 3.75 kΩ, 7.5 kΩ, and 15 kΩ with the 1 mA current source.

The NI 435*x* can measure resistances to its specified accuracy as long as the voltage across the resistors is within the selected input range specified above. To get the best resolution, noise rejection, and accuracy, choose the smallest range in which the signals can be accommodated. Make sure that each signal input to CH+ and CH– is within the input common-mode limits of its input range and that the total resistance connected to the current excitation source does not exceed its maximum load.

To determine the most suitable input range for the application, estimate the voltage developed across the resistor by following the procedure outlined in Figures 2-7 and 2-8. Estimate the common-mode voltage at the inputs, and verify that the range you select can handle that common-mode voltage. Refer to the *Maximum Working Voltage* section of Appendix A, *Specifications*, for the maximum voltage per range.

To determine if the current excitation source can handle the load you are connecting to it, calculate the total load by adding the resistance value of all resistors, RTDs, and thermistors connected in series to the current excitation. Use the maximum resistance value that the RTDs and thermistors will reach in your measurements. Verify that this load is within the allowed limits. Refer to the *Excitation* section of Appendix A, *Specifications*, for the maximum load resistance.

For resistance higher than 25 kΩ, a settling time of over 1 s may be required when changing channels, to achieve the specified accuracy.

The NI 435*x* analog inputs are protected against damage from voltages within ±42 VDC in all ranges when powered on and ±17 VDC when powered off.

Caution *Never* apply voltages above these levels to the inputs. To prevent possible safety hazards, the maximum voltage between any of the analog inputs and the computer ground should never exceed ±42 VDC when the NI 435*x* is powered on and ±17 VDC when the NI 435*x* is powered off.

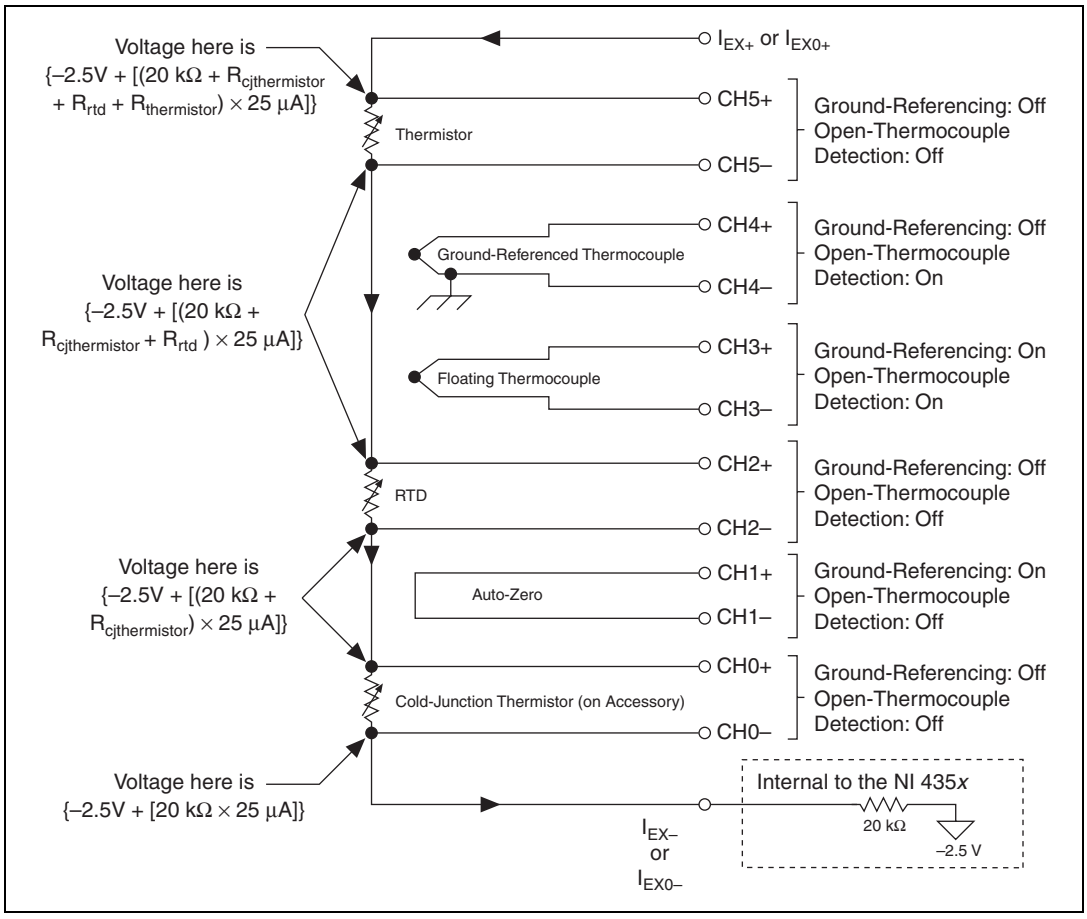


Figure 2-7. Multiple Transducer Connections to Analog Channels in One Measurement Setup, Channels 0–5

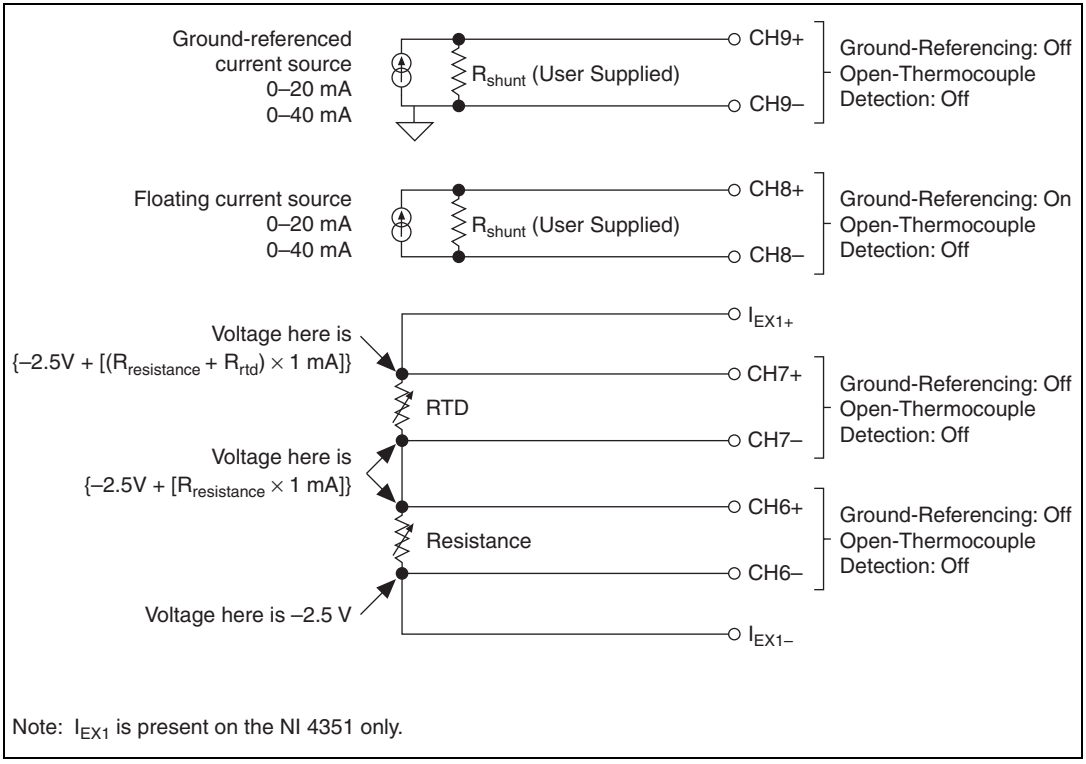


Figure 2-8. Multiple Transducer Connections to Analog Channels in One Measurement Setup, Channels 6–9

Introduction to RTDs

An RTD is a temperature-sensing device whose resistance increases with temperature. An RTD consists of a wire coil or deposited film of pure metal. RTDs can be made of different metals and can have different resistances, but the most popular RTD is made of platinum and has a nominal resistance of 100 Ω at 0 °C.

RTDs are known for their excellent accuracy over a wide temperature range. Some RTDs have accuracy as high as 0.01 Ω (0.026 °C) at 0 °C. RTDs are also extremely stable devices. Common industrial RTDs drift less than 0.1 °C/year, and some models are stable to within 0.0025 °C/year.

RTDs can be difficult to measure because they have relatively low resistance (100 Ω) that changes only slightly with temperature (less than 0.4 Ω/°C). To accurately measure these small changes in resistance, you may need to use special configurations that minimize errors from lead wire resistance.

Relationship of Resistance and Temperature in RTDs

Compared to other temperature devices, the output of an RTD is relatively linear with respect to temperature. The temperature coefficient, alpha (α), differs between RTD curves. Although various manufacturers may specify α differently, α is most commonly defined as the change in RTD resistance from 0 °C to 100 °C, divided by the resistance at 0 °C, divided by 100 °C as follows:

$$\alpha\ (\Omega/\Omega/°C) = [(R_{100} - R_0)/R_0]/100\ °C$$

where R_{100} is the resistance of the RTD at 100 °C, and R_0 is the resistance of the RTD at 0 °C.

For example, a 100 Ω platinum RTD with α = 0.00385 measures 138.5 Ω at 100 °C. Figure 2-9 shows a typical resistance-temperature curve for a 100 Ω platinum RTD.

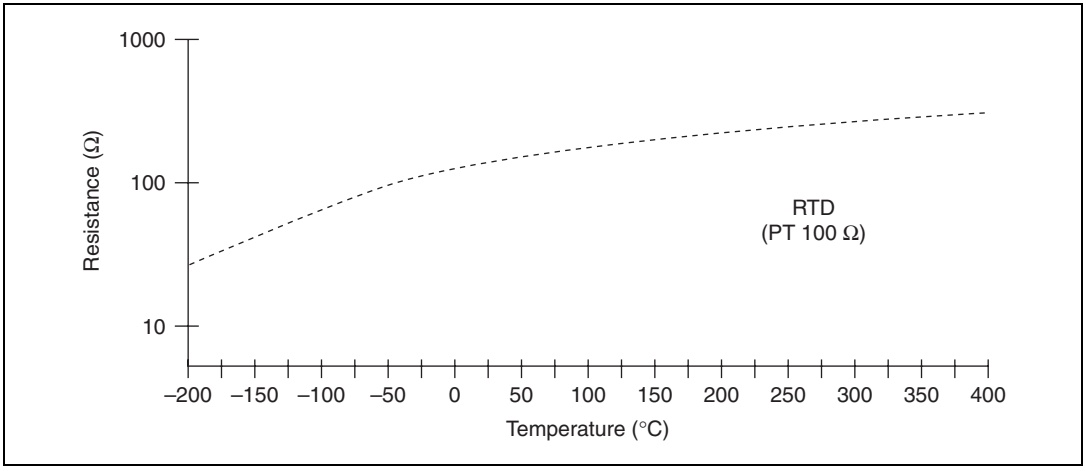


Figure 2-9. Resistance-Temperature Curve for a 100 Ω Platinum RTD

Although the resistance-temperature curve is relatively linear, converting measured resistance to temperature accurately requires curve fitting. The Callendar-Van Dusen equation is commonly used to approximate the RTD curve:

$$R_{RTD} = R_0[1 + A \times t + B \times t^2 + C \times (t - 100) \times t^3]$$

where R_{RTD} is the resistance of the RTD at temperature T_{RTD}; R_0 is the resistance of the RTD in Ω at 0 °C; *A*, *B*, and *C* are the Callendar-Van Dusen coefficients shown in Table 2-4; and T_{RTD} is the temperature in °C. For temperatures above 0 °C, coefficient *C* equals 0. Therefore, for temperatures above 0 °C, this equation reduces to a quadratic:

$$T_{RTD} = \frac{2\left(\frac{R_{RTD}}{R_0} - 1\right)}{A + \sqrt{A^2 + 4B\left(\frac{R_{RTD}}{R_0} - 1\right)}}$$

Most platinum RTD curves follow one of three standardized curves: the DIN 43760 standard ($\alpha = 0.00385$), the U.S. Industrial or American standard ($\alpha = 0.003911$), or the International Temperature Scale (ITS-90), which is used with wire-wound RTDs ($\alpha = 0.003925$). Table 2-4 lists the Callendar-Van Dusen coefficients for each of these three platinum RTD curves.

Table 2-4. Callendar-Van Dusen Coefficients Corresponding to Common RTDs

Standard	Temperature Coefficient (α)	A	B	C*
IEC751	0.00385055	3.9083×10^{-3}	-5.775×10^{-7}	-4.183×10^{-1}
DIN 43760	0.003850	3.9080×10^{-3}	-5.8019×10^{-7}	-4.2735×10^{-12}
American	0.003911	3.9692×10^{-3}	-5.8495×10^{-7}	-4.2325×10^{-12}
ITS-90	0.003925	3.9848×10^{-3}	-5.870×10^{-7}	-4.0000×10^{-12}
* For temperatures below 0 °C only; C = 0.0 for temperatures above 0 °C.				

Note NI software packages, such as NI-435*x*, MAX Create New Channel Wizard, LabVIEW, and LabWindows/CVI, include routines that perform these conversions for different types of RTDs based on the various commonly used standards.

Connecting the RTD

You can use signal connection techniques described in the *Connecting Resistors* section for any RTD.

The preferred RTD measurement method is to use a 4-wire connection, as shown in Figure 2-4, to minimize errors due to lead resistance. For example, if you connect an RTD in a 2-wire configuration as shown in Figure 2-3, a lead resistance, R_L, of 0.3 Ω in each wire results in a 0.6 Ω error. For a platinum RTD with $\alpha = 0.00385$, this error equals a 0.6 Ω/(0.385 Ω/°C) = 1.6 °C error. By connecting the RTD in a 4-wire configuration, this error is no longer present in the measurement.

Alternatively, you can use a 3-wire RTD configuration, as shown in Figures 2-5 and 2-6.

Note In the 3-wire connections shown in Figure 2-6, the effects of the lead-wire resistance cancel out as long as all three wires have the same lead resistance, while in the connections shown in Figure 2-5 the resistance of only one lead adds error to the measurement.

You can use the same current excitation for several resistors as long as you do not exceed the maximum load and are within the common-mode voltage specification. Refer to the *Input Ranges* section in the *Connecting Resistors* section for more information about connection precautions and for examples of how you can use different transducers connected to analog channels in the same measurement setup.

Note For best results, use the 1 mA current source when using the NI 4351 with RTDs with resistances below 1 kΩ. For resistances above 1 kΩ or with the NI 4350, use the 25 µA current source to avoid self-heating. Refer to the *Self-Heating* section for further details.

Introduction to Thermistors

A thermistor is a piece of semiconductor made from metal oxides, pressed into a small bead, disk, wafer, or other shape, which is sintered at high temperatures and finally coated with epoxy or glass. The resulting device exhibits an electrical resistance that varies with temperature.

There are two types of thermistors—negative temperature coefficient (NTC) thermistors and positive temperature coefficient (PTC) thermistors. An NTC thermistor is one whose resistance decreases with increasing temperature. A PTC thermistor is one whose resistance increases with increasing temperature. NTC thermistors are much more commonly used than PTC thermistors, especially for temperature measurement applications.

A main advantage of thermistors for temperature measurement is their high sensitivity. For example, a 2,252 Ω thermistor has a sensitivity of –100 Ω/°C at room temperature. Higher resistance thermistors can exhibit temperature coefficients of –10 kΩ/°C or more. In comparison, a 100 Ω platinum RTD has a sensitivity of only 0.4 Ω/°C. The small size of the thermistor bead also yields a fast response to temperature changes.

Another advantage of the thermistor is its relatively high resistance. Thermistors are available with base resistances (at 25 °C) ranging from hundreds to millions of ohms. This high resistance diminishes the effect of inherent resistances in the lead wires, which can cause significant errors with low resistance devices such as RTDs. For example, while RTD measurements typically require 4-wire or 3-wire connections to reduce errors caused by lead wire resistances, 2-wire connections to thermistors are usually adequate.

The major trade-off for the high resistance and sensitivity of the thermistor is its highly nonlinear output and relatively limited operating range. Depending on the type of thermistors, upper ranges are typically limited to around 300 °C. Figure 2-10 shows the resistance-temperature curve for a 5,000 Ω thermistor. The curve of a platinum 100 Ω RTD also is shown for comparison.

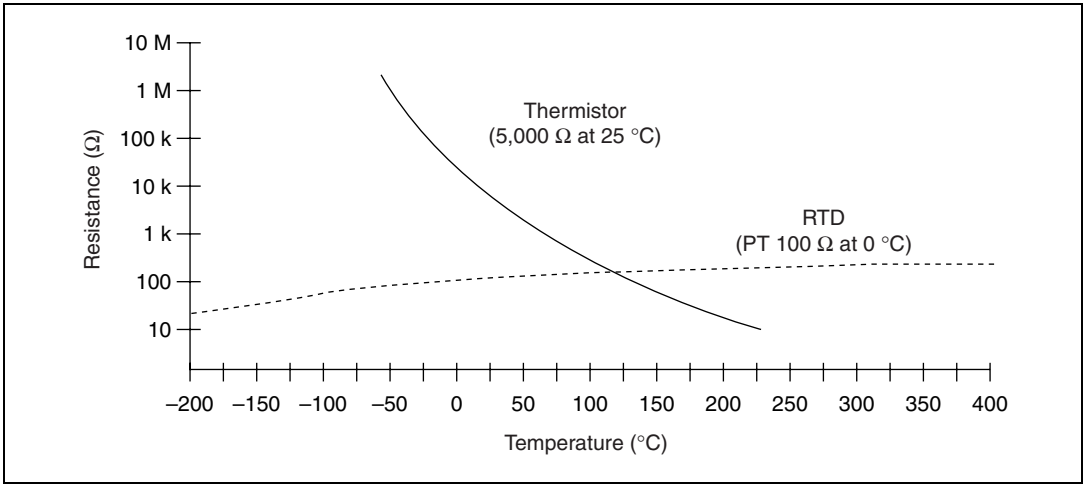


Figure 2-10. Resistance-Temperature Curve of a Thermistor

The thermistor has been used primarily for high-resolution measurements over limited temperature ranges. Continuous improvements in thermistor stability, accuracy, and availability of interchangeable thermistors have prompted increased usage of thermistors in all types of industries.

Resistance-Temperature Characteristic of Thermistors

The resistance-temperature behavior of thermistors is highly dependent upon the manufacturing process. Therefore, thermistor manufacturers have not standardized thermistor curves to the extent that thermocouple or RTD curves are standardized.

Typically, thermistor manufacturers supply the resistance-versus-temperature curves or tables for their particular devices. The thermistor curve, however, can be approximated relatively accurately with the Steinhart-Hart equation:

$$T(\mathrm{K}) = \frac{1}{a + b \times \ln(R_t) + c \times \ln^3(R_t)}$$

Where T(K) is the temperature in kelvin, equal to T(°C) + 273.15, and R_t is the resistance of the thermistor. The coefficients a, b, and c can be provided by the thermistor manufacturer, or calculated from the resistance-versus-temperature curve.

Software packages such as LabVIEW and LabWindows/CVI include routines that perform these conversions for some types of thermistors. You also can modify these conversion routines for the particular type of thermistor.

Connecting the Thermistor

You can use signal connection techniques described in the *Connecting Resistors* section for any thermistor.

The high resistance and high sensitivity of the thermistor simplify the necessary measurement circuitry and signal conditioning. 3-wire or 4-wire connections, as shown in Figures 2-4, 2-5, and 2-6, are not necessary. The value of the lead resistance is negligible compared to the resistance value of the thermistor. Therefore, a 2-wire connection, as shown in Figure 2-3, is sufficient.

You can use the same current excitation for several resistors as long as you do not exceed the maximum load and are within the common-mode voltage specification. Refer to the *Input Ranges* section in the *Connecting Resistors* section for more information about connection precautions and for examples of how you can use different transducers connected to analog channels in the same measurement setup.

Note Use the 25 µA current source for thermistors above 1 kΩ to avoid self-heating. Refer to the *Self-Heating* section for further details.

Optimizing Measurements

In addition to the potential problems discussed in the sections on connecting the RTDs and thermistors, also consider other problems associated with AC noise effects, thermal EMF, and other errors as discussed in the following sections.

Auto Zero

Auto Zero removes any offset errors in the measurement. Analog channel 1 (CH1) on the TC-2190, TBX-68T, and CB-68T is dedicated for Auto Zero. CH1+ is connected to CH1– on these accessories. When using a TBX-68 accessory, connect CH– to CH+ (any channel) to make that channel useful for Auto Zero. You can measure the voltage offset on this Auto Zero channel and subtract it from the voltage measurements on other channels. This way, you can compensate for any residual offset error. This is especially useful when the NI 435*x* is operating at an ambient temperature other than that of calibration (23 °C typical).

Programmable Ground-Referencing

Always switch off ground-referencing on the channel connected to a resistor excited by the current source. The current source return terminals, I_{EX-}, I_{EX0-}, and I_{EX1-}, are tied to –2.5 V through internal circuits. This –2.5 V causes any resistor excited by the current source to be ground-referenced. Otherwise, the leakage current flowing into the resistor can cause erroneous measurements for all channels that use the current source.

Programmable Open-Thermocouple Detection

Always switch off open-thermocouple detection on the channel connected to a resistor. Otherwise, the leakage current flowing into the resistor can cause erroneous measurements for all channels that use the current source.

Connecting to External Circuits

Refer to Figures 2-7 and 2-8 for examples of how different transducers connect to analog channels in the same measurement setup. To measure the value of a resistor accurately, make sure the resistor is not electrically connected to any other circuits. Erroneous or misleading readings can result if the resistor you are measuring is electrically connected to external circuits that supply voltages or currents, or if the measured resistor is connected to external circuits that change the effective resistance.

2-Wire, 3-Wire, and 4-Wire Measurements

The *Connecting Resistors* section discusses whether to use 2-wire, 3-wire, or 4-wire setups, and applies to any resistance measurement. Choose the appropriate measurement technique for the application as shown in Table 2-5.

Table 2-5. Guidelines for Resistance Measurements

Measured Resistance (Ω)	Measurement Technique
$R \leq 1\ k\Omega$	4-wire
$1\ k\Omega < R \leq 10\ k\Omega$	4-wire or 3-wire
$R > 10\ k\Omega$	4-wire, 3-wire, or 2-wire

Self-Heating

The current source on the NI 435*x* is designed so that error resulting from self-heating is negligible in most cases.

When current is passed through an RTD or a thermistor (both are resistive devices), the power dissipated is equal to I^2R and heats the resistive devices. This self-heating is typically specified by manufacturers in the form of the dissipation constant. The dissipation constant is the power required to heat the thermistor by 1 °C from ambient temperature, and it is usually represented in units of mW/°C. The dissipation constant depends significantly on how easily heat is transferred away from the thermistor, so the dissipation constant may be specified for different media—in still air, water, or oil bath.

Thermistors, with their small size and high resistance, are particularly prone to these self-heating errors. Typical dissipation constants range anywhere from less than 0.5 mW/°C for still air to 10 mW/°C or higher for a thermistor immersed in water. A 5,000 Ω thermistor powered by a 25 µA excitation current dissipates as follows:

$$I^2R = (25\ \mu A)^2 \times 5{,}000\ \Omega = 3.1\ \mu W$$

If this thermistor has a dissipation constant of 10 mW/°C, the thermistor self-heats by only 0.003 °C. Thus, the small value of the current source helps prevent any appreciable error due to self-heating.

RTDs are relatively immune to the problem of self-heating, because their resistance is relatively small, such as 100 Ω at 0 °C. Also, the amount of self-heating depends significantly on the medium in which the RTD is immersed. An RTD can self-heat up to 100 times higher in still air than in moving water. The self-heating in RTDs that is due to the built-in 25 µA is negligible. When using 1 mA excitation current, a 100 Ω RTD dissipates as follows:

$$I^2R = (1\ mA)^2 \times 100\ \Omega = 0.1\ mW$$

If this RTD has a dissipation constant of 5 mW/°C, the RTD self-heats by 0.02 °C.

AC Noise Effects

The NI 435*x* rejects AC noise as specified in NMR in Appendix A, *Specifications*. However, if the amplitudes of the AC noise are large compared to the DC signal, or if the peak value (AC plus DC) of the

measured signal is outside the input range, the NI 435*x* may exhibit additional errors. To minimize these errors, keep the signal source, the NI 435*x*, and its accessory away from strong AC magnetic sources and minimize the area of the loop formed by the wires connecting the signal source with the accessory. Choosing the notch filter frequency of 10 Hz provides the best AC noise rejection. If the peak value of the measured voltage is likely to exceed the selected input range, select the next higher input range.

Thermal EMF

Thermoelectric potentials or thermal EMFs are voltages generated at the junctions of dissimilar metals and are functions of temperature. Thermal EMFs in the source generating the signal can introduce errors in measurements that change with variations in temperature.

To minimize thermal EMFs, use copper wires to connect the signal to the NI 435*x* accessory. Avoid using dissimilar metal wires in connections. Also, keep out temperature gradients in the space enclosing the signal source, the NI 435*x*, and its accessories.

Using Digital Inputs and Outputs

The NI 435*x* features TTL-compatible digital lines. These lines can be individually configured either as digital inputs or as outputs. When the NI 435*x* hardware powers on, these digital lines are configured as high-impedance inputs.

You can use the DIO lines as an interface to control processes, to control events such as turning on and off heaters, relays, motors, or lights, to generate patterns for testing, and to communicate with peripheral equipment. If the current and voltage specifications of the DIO lines are not appropriate for the requirements, you can use external signal conditioning such as electromechanical relay, solid-state relay, opto-coupler, and so on.

You can use the digital input lines to trigger analog acquisitions. To trigger analog acquisitions with LabVIEW or NI-435*x*, set up the analog acquisition configuration, poll the digital input line for the trigger condition, and start the analog acquisition after receiving the trigger.

Connecting the Digital Input and Output

All NI 435*x* accessories are designed to be used for DIO. Refer to the accessory installation guide for instructions on how to connect the DIO lines. Figure 2-11 shows examples of how to connect DIO lines for various applications such as controlling an LED, monitoring a TTL-compatible or CMOS-compatible signal, monitoring a low-voltage switch, and monitoring a low-voltage transistor.

For the NI 435*x* for PXI, PCI, and USB, you can use the TBX-68T (revision C or later) and the CB-68T to connect to digital signal conditioning accessories with optocouplers, solid-state relays, and electromechanical relays, such as the SC-2061, SC-2062, SC-2063, SSR Series, and ER Series.

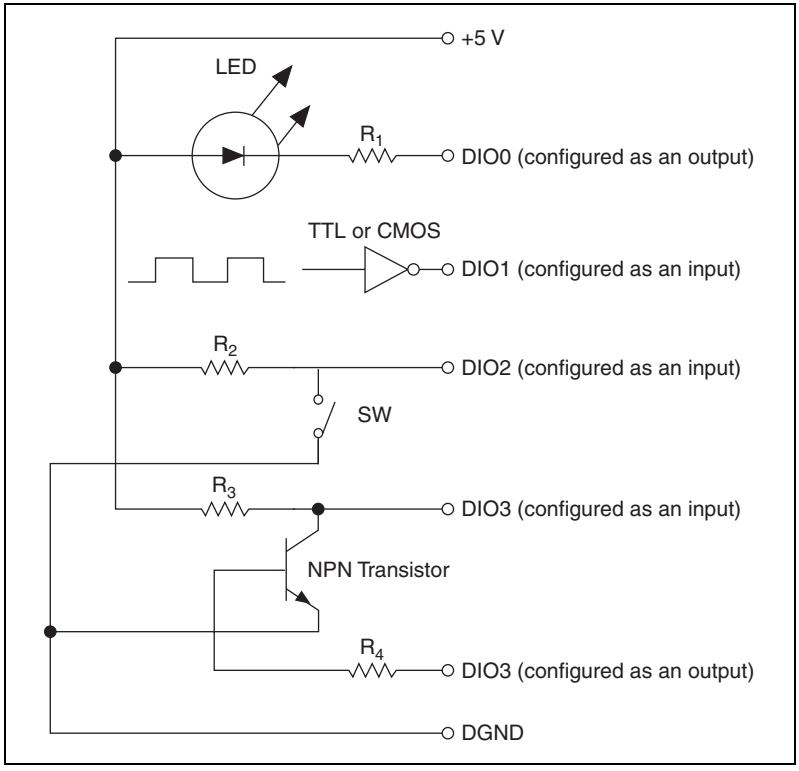


Figure 2-11. Examples of DIO Applications

Caution To prevent possible safety hazards, the voltage applied to the digital I/O lines should *never* be outside –0.5 V and +5.5 V, with respect to DGND.

The DIO lines of the NI 435*x* are protected against damage from voltages within –0.5 and +5.5 V with respect to digital ground (DGND). Never apply voltages above these levels to these signals.

Note If the number of digital input lines is inadequate for the application, use the analog input channels to measure the voltage of the digital signal you want to measure. Determine the logic level based on the thresholds of the logic family of the digital signal. Table 2-6 shows thresholds of CMOS and TTL logic families using analog inputs as digital inputs.

Table 2-6. Logic Family Thresholds

Logic Family	Low	High
CMOS	<0.8 V	>2.0 V
TTL	<0.8 V	>2.0 V
Note: Check the logic family data sheets for any variations.		

A

Specifications

This appendix lists the specifications of the NI 4350 and NI 4351. These specifications are for a 15 °C to 35 °C ambient temperature range within one year of calibration unless otherwise specified. All specifications are relative to calibration standards and require a 30 minute warm-up period. Specifications do not include transducer errors. Temperature coefficient is applicable for 0 °C to 15 °C and 35 °C to 55 °C. For thermocouples, add the accessory error in °C only if the accessory (TC-2190, TBX-68T, or CB-68T) is in the 0 °C to 15 °C and 35 °C to 55 °C temperature range.

Accuracy Specifications

Thermocouple Accuracy*

Thermocouple Type	°C	Error (°C) 15 °C to 35 °C, 1 Year			0 °C to 15 °C, 35 °C to 55 °C	
		Filter Setting			Temperature Coefficient (°C/°C†)	Accessory Error (°C‡)
		10 Hz	50 Hz	60 Hz		
J	–100	0.53	0.61	0.74	0.02	0.25
	0	0.42	0.49	0.59		
	760	0.42	0.47	0.55		
K	–100	0.60	0.72	0.89	0.03	0.27
	0	0.45	0.54	0.67		
	1,000	0.60	0.69	0.81		
	1,372	0.74	0.84	0.99		

Thermocouple Type	°C	Error (°C) 15 °C to 35 °C, 1 Year			0 °C to 15 °C, 35 °C to 55 °C	
		Filter Setting			Temperature Coefficient (°C/°C†)	Accessory Error (°C‡)
		10 Hz	50 Hz	60 Hz		
N	–100	0.68	0.84	1.08	0.03	0.26
	0	0.54	0.67	0.86		
	400	0.42	0.51	0.65		
	1,300	0.57	0.66	0.80		
E	–100	0.55	0.62	0.74	0.02	0.28
	0	0.41	0.46	0.55		
	500	0.35	0.40	0.46		
	1,000	0.46	0.50	0.57		
T	–150	0.81	0.96	1.17	0.03	0.36
	0	0.46	0.55	0.68		
	400	0.33	0.39	0.47		
R	250	0.82	1.16	1.65	0.06	0.12
	1,000	0.72	0.99	1.37		
	1,767	0.91	1.19	1.60		
S	250	0.91	1.28	1.83	0.07	0.13
	1,000	0.77	1.05	1.47		
	1,767	0.96	1.27	1.72		
B	600	1.08	1.64	2.47	0.11	0.00
	1,000	0.76	1.14	1.69		
	1,820	0.74	1.05	1.50		

* Thermocouple measurement specifications include cold-junction compensation error (with sensor between 15 °C and 35 °C), isothermal accuracy, and system noise. The specifications assume that the 0.625 V range is used and that ground-referencing and open-thermocouple detection are enabled for a floating thermocouple. Specifications improve with ground-referencing enabled and open-thermocouple detection disabled for a floating thermocouple. The specifications also assume that the cold-junction sensor is between 15 °C and 35 °C.

† Add when the thermocouple accessory and the NI 435*x* are outside of the 15 °C to 35 °C temperature range.

‡ Add when the thermocouple accessory is outside of the 15 °C to 35 °C temperature range.

RTD Accuracy (with I_{EX} or I_{EX0})*

RTD	°C	Error (°C) 15 °C to 35 °C, 1 Year			0 °C to 15 °C, 35 °C to 55 °C
		Filter Setting			Temperature Coefficient (°C/°C)
		10 Hz	50 Hz	60 Hz	
Pt 100 Ω	–200	1.00	1.33	1.81	0.01
	0	1.14	1.49	2.00	
	100	1.22	1.58	2.10	
	300	1.38	1.76	2.32	
	600	1.66	2.08	2.69	

* RTD specifications assume that the 25 kΩ (25 µA current source) range is used and worst case common-mode voltage for this range is present. Specifications improve if actual common-mode voltage is less than worst case. Specifications improve for a 1,000 Ω RTD.

RTD Accuracy (with I_{EX1})*

RTD	°C	Error (°C) 15 °C to 35 °C, 1 Year			0 °C to 15 °C, 35 °C to 55 °C
		Filter Setting			Temperature Coefficient (°C/°C)
		10 Hz	50 Hz	60 Hz	
Pt 100 Ω	–200	0.05	0.06	0.07	0.01
	0	0.12	0.13	0.14	
	100	0.16	0.17	0.18	
	300	0.23	0.24	0.26	
	600	0.36	0.37	0.39	

* RTD specifications assume that the 625 Ω range (1 mA current source) is used and worst case common-mode voltage for this range is present. Specifications improve if actual common-mode voltage is less than worst case.

Thermistor Accuracy (with I_{EX} or I_{EX0})*

Thermistor	°C	Accuracy (°C) 15 °C to 35 °C, 1 Year, Filter Setting: 10 Hz, 50 Hz, 60 Hz	Temperature Coefficient 0 °C to 15 °C, 35 °C to 55 °C
		°C	°C/°C
5,000 Ω	0 to 50	0.03	0.001

* Thermistor accuracy is valid for all filter settings. Specifications assume that the 25 kΩ range is used and worst case common-mode voltage for this range is present. Specifications improve if actual common-mode voltage is less than worst case.

DC Voltage Accuracy*

Range (Volts)	% of Reading 15 °C to 35 °C			Add µV (with Auto Zero) 15 °C to 35 °C Filter Setting			Add µV (without Auto Zero) 15 °C to 35 °C Filter Setting			Temperature Coefficient 0 °C to 15 °C, 35 °C to 55 °C	
	24 Hour	90 Day	1 Year	10 Hz	50 Hz	60 Hz	10 Hz	50 Hz	60 Hz	% Reading/ °C	µV/°C
15	0.0146	0.0175	0.0205	28	117	141	130	193	210	0.0009	5
7.5	0.0152	0.0181	0.0211	21	71	106	125	160	185	0.0009	5
3.75	0.0164	0.0193	0.0223	14	30	42	120	131	140	0.0010	5
2.5	0.0066	0.0095	0.0125	5	17	24	24	32	37	0.0004	1
1.25	0.0072	0.0101	0.0131	3	12	18	22	29	33	0.0004	1
0.625	0.0084	0.0113	0.0143	2	6	11	22	24	28	0.0005	1

* Voltage specifications do not include errors resulting from common-mode voltages. Calculate additional common-mode voltage errors as: common-mode voltage/$10^{(\text{CMR specification in db}/20)}$.

Note To learn how to calculate DC voltage accuracy, and if you have a thermistor other than 5,000 K, refer to `ni.com\support` and click **KnowledgeBase** under *Option 3*. Enter `1W3E9CHE` in the search field to access the entry called *Calculating the Accuracy of a Specific Resistive Sensor.*

Resistance Accuracy (with I_{EX} or I_{EX0})*

Range (W)	% of Reading 15 °C to 35 °C			Add Ω (with Auto Zero) 15 °C to 35 °C			Add Ω (without Auto Zero) 15 °C to 35 °C			Temperature Coefficient 0 °C to 15 °C, 35 °C to 55 °C
				Filter Setting			Filter Setting			
	24 Hour	90 Day	1 Year	10 Hz	50 Hz	60 Hz	10 Hz	50 Hz	60 Hz	%Reading/°C
600,000	0.0435	0.0464	0.0494	20.11	23.64	24.63	24.17	26.67	27.37	0.0013
300,000	0.0441	0.0470	0.0500	19.82	21.80	23.22	23.97	25.37	26.37	0.0013
150,000	0.0453	0.0482	0.0512	19.54	20.16	20.67	23.77	24.21	24.57	0.0013
100,000	0.0355	0.0384	0.0414	0.51	1.00	1.28	1.26	1.60	1.80	0.0013
50,000	0.0361	0.0390	0.0420	0.45	0.80	1.02	1.21	1.46	1.62	0.0013
25,000	0.0373	0.0402	0.0432	0.41	0.54	0.74	1.18	1.28	1.42	0.0013

* Resistance specifications assume worst case common-mode voltage for the given range. Specifications improve if actual common-mode voltage is less than worst case. Measurement accuracy is affected by source impedance. Resistances >25 kΩ may require 1 s setting time.

Resistance Accuracy (with I_{EX1})*

Range (W)	% of Reading 15 °C to 35 °C			Add Ω (with Auto Zero) 15 °C to 35 °C			Add Ω (without Auto Zero) 15 °C to 35 °C			Temperature Coefficient 0 °C to 15 °C, 35 °C to 55 °C
				Filter Setting			Filter Setting			
	24 Hour	90 Day	1 Year	10 Hz	50 Hz	60 Hz	10 Hz	50 Hz	60 Hz	%Reading/°C
15,000	0.0320	0.0349	0.0379	1.53	1.62	1.64	1.63	1.69	1.71	0.0013
7,500	0.0326	0.0355	0.0385	1.52	1.57	1.61	1.63	1.66	1.69	0.0013
3,750	0.0338	0.0367	0.0397	1.51	1.53	1.54	1.62	1.63	1.64	0.0013
2,500	0.0240	0.0269	0.0299	0.03	0.04	0.05	0.05	0.06	0.06	0.0013
1,250	0.0246	0.0275	0.0305	0.03	0.04	0.04	0.05	0.05	0.06	0.0013
625	0.0258	0.0287	0.0317	0.02	0.02	0.02	0.04	0.04	0.04	0.0013

* Resistance specifications assume worst case common-mode voltage for the given range. Specifications improve if actual common-mode voltage is less than worst case. Measurement accuracy is affected by source impedance.

Accuracy Calculation Examples

The following are accuracy calculation examples:

- Measurement of 760 °C using J-type thermocouple at 28 °C ambient temperature; filter setting of 10 Hz:

  accuracy is 0.42 °C

- Measurement of 760 °C using J-type thermocouple with NI 4350 at 38 °C and accessory (cold-junction sensor) at 23 °C; filter setting of 10 Hz:

  accuracy is 0.48 °C as a result of
  [0.42 °C + (38 °C to 35 °C) × 0.02]

- Measurement of 760 °C using J-type thermocouple with NI 4350 and accessory (cold-junction sensor) at 38 °C; filter setting of 10 Hz:

  accuracy is 0.73 °C as a result of
  [0.42 °C + (38 °C to 35 °C) × 0.02 + 0.25 °C]

- Measurement of 1 V using 1.25 V range, filter setting of 60 Hz at 28 °C ambient temperature after 90 days of calibration with Auto Zero; at 0 V common-mode voltage:

  accuracy is 119 µV as a result of
  [1 V × 0.0101% +18 µV]

- Measurement of 1 V using 1.25 V range, filter setting of 60 Hz at 38 °C ambient temperature after 90 days of calibration, with Auto Zero; at 0.5 V common-mode voltage:

  accuracy is 139 µV, as a result of
  [1 V × 0.0101% +18 µV + (38 °C to 35 °C) ×
  {1 V × 0.0004%/°C + 1 µV/°C}+ $(0.5V/10^{100/20})$]

Analog Input

Input Characteristics

Number of channels ..... 16 differential
or 14 thermocouple

Digits 5 1/2

Type of ADC ..... Sigma-delta

ADC resolution ..... 24 bits, no missing codes

Calibration cycle ..... 1 year

Input coupling ..... DC

Over-voltage protection
(CH<0..8/15>, $I_{EX\pm}$, $I_{EX0\pm}$, $I_{EX1\pm}$) ..... ±42 V powered on;
±17 V powered off

Data transfers ..... Interrupts, programmed I/O

Warm-up time ..... 30 minutes

Amplifier Characteristics

Input impedance

- Normal powered on ..... >1 GΩ in parallel with 0.39 µF
- Powered off ..... 10 kΩ
- Overload ..... 10 kΩ

Open-thermocouple detection ..... 10 MΩ between CH+ and +2.5 V
(software-selectable)

Ground-referencing ..... 10 MΩ between CH– and ground
(software-selectable)

Input bias current ..... <500 pA

CMR (DC, 50 Hz, 60 Hz, 400 Hz)

- Range ≥2.5 V ..... 80 dB
- Range <2.5 V ..... 100 dB

NMR (50 Hz, 60 Hz, 400 Hz) ..... >100 dB

Dynamic Characteristics

Bandwidth.....20 Hz

Step response (full-scale step)

Accuracy	Time(s)
±0.1%	0.3
±0.01%	0.5
±0.0015%	2.4
±0.001%	3
±0.0004%	7

Excitation

Note The exact value of the excitation current is stored on the hardware. NI-DAQ uses this value when taking resistance measurements.

Number of channels.....2

Parameter	I_{EX} or I_{EX0}	I_{EX1}
Level	25 µA	1 mA[1]
Maximum Load Resistance	600 kΩ	15 kΩ
Temperature Coefficient	±15 ppm/°C	±15 ppm/°C

[1] The 1 mA excitation level is only available on the NI 4351.

Digital I/O and Alarm Outputs

Number of lines..... 8

Compatibility ..... TTL

DIO<0..3/7>

Level	Minimum	Maximum
Input low voltage	0.0 V	0.8 V
Input high voltage	2.0 V	5.0 V (V_{CC})
Input low current (V_{in} = 5 V)	—	–10 µA
Input high current (V_{in} = 5 V)	—	10 µA
Output low voltage (I_{out} = 8 mA)	—	0.4 V
Output high voltage (I_{out} = 8 mA)	3.8 V	—

Power-on state..... Tristate

Data transfers ..... Programmed I/O

Bus Interface

Type ..... Slave (plug-and-play)

Power Requirements

USB..... High-power, USB-powered peripheral (500 mA)

PXI ..... 480 mA at +5 V

PCI ..... 480 mA at +5 V

Power available at I/O connector..... +4.6 V to +5.2 V, 1 A (PXI, PCI); +4.6 V to +5.2 V, 50 mA (USB)

Physical

Dimensions

USB .....14.6 × 21.3 × 3.8 cm
(5.8 × 8.4 × 1.5 in.)

PXI.....3 U, one slot, PXI/cPCI module
2.0 × 13.0 × 21.6 cm
(0.8 × 5.1 × 8.5 in.)

PCI.....PCI (half size)

I/O connector .....68-pin male,
shielded and latched

Maximum Working Voltage

Maximum working voltage refers to the signal voltage plus the common-mode voltage.

Range >2.5 V.....Each input should remain within ±15 V of ground

Range ≤2.5 V.....Each input should remain within ±2.5 V of ground

Environmental

Operating temperature .....0 °C to 55 °C

Storage temperature.....–20 °C to 70 °C

Humidity .....Up to 80% RH, noncondensing

Maximum altitude.....2,000 m

Measurement Category.....I

Pollution Degree (indoor use only) 2

Caution Do *not* use for measurements within Categories II, III, or IV.

Safety

- PCI/PXI Only

  The NI PCI/PXI-435*x* meets the requirements of the following standards of safety for electrical equipment for measurement, control, and laboratory use:

  - IEC 61010-1, EN 61010-1
  - UL 61010-1
  - CAN/CSA-C22.2 No. 61010-1

Note For UL and other safety certifications, refer to the product label, or visit `ni.com/certification`, search by model number or product line, and click the appropriate link in the Certification column.

Electromagnetic Compatibility

Emissions	EN 55011 Class A at 10 m FCC Part 15A above 1 GHz
Immunity	EN 61326:1997 + A2:2001, Table 1
EMC/EMI	CE, C-Tick, and FCC Part 15 (Class A) Compliant

Note For EMC compliance, operate this device with shielded cabling.

CE Compliance

The NI 435*x* devices meet the essential requirements of applicable European Directives, as amended for CE marking, as follows:

Low-Voltage Directive (safety)	73/23/EEC
Electromagnetic Compatibility Directive (EMC)	89/336/EEC

Note Refer to the Declaration of Conformity (DoC) for this product for any additional regulatory compliance information. To obtain the DoC for this product, visit `ni.com/certification`, search by model number or product line, and click the appropriate link in the Certification column.

B

Signal Connections

This section lists the pinouts of the NI 435*x*.

The TBX-68 accessory is an extension of the connector of the NI 435*x* device; therefore, the pinout of the screw terminal of the TBX-68 corresponds to the pinout of the NI 435*x* device.

Table B-1 shows how the screw terminals on the TBX-68 connector block, and the SH6868 cable and the R6868 cables correspond to the signal names on the NI 435*x* (USB, PXI, PCI).

Table B-1. Using the NI 435*x* (USB, PXI, PCI) with the TBX-68

NI 435*x* (USB, PXI, PCI) Signal Name	TBX-68 Screw Terminal
CH0+	68
CH0–	34
CH1+	33
CH1–	66
CH2+	65
CH2–	31
CH3+	30
CH3–	63
CH4+	62
CH4–	29
CH5+	28
CH5–	61
CH6+	60
CH6–	26
CH7+	25

Table B-1. Using the NI 435*x* (USB, PXI, PCI) with the TBX-68 (Continued)

NI 435*x* (USB, PXI, PCI) Signal Name	TBX-68 Screw Terminal
CH7–	58
CH8+	57
CH8–	23
CH9+	22
CH9–	55
CH10+	54
CH10–	21
CH11+	19
CH11–	53
CH12+	52
CH12–	18
CH13+	17
CH13–	50
CH14+	49
CH14–	15
CH15+	13
CH15–	46
I_{EX+}, I_{EX0+} (NI 4351)	12
$I_{EX–}$, $I_{EX0–}$ (NI 4351)	45
I_{EX1+} (NI 4351 only)	44*
$I_{EX1–}$ (NI 4351 only)	10*
DIO0	7
DIO1	6
DIO2	5
DIO3	4

Table B-1. Using the NI 435*x* (USB, PXI, PCI) with the TBX-68 (Continued)

NI 435*x* (USB, PXI, PCI) Signal Name	TBX-68 Screw Terminal
DIO4	37
DIO5	3
DIO6	2
DIO7	1
+5V	8†
DGND	35, 36, 38, 39, 40, 41, 42
AGND	9, 10, 11, 14, 16, 20, 24, 27, 32, 43, 44, 47, 48, 51, 56, 59, 64, 67

* Screw terminals 10 and 44 are AGND on the NI 4350 only and are not labeled AGND on revision C or later of the TBX-68T.

† The current available may be limited to less than 50 mA (typical) when using the NI USB-4350.

C

Technical Support and Professional Services

Visit the following sections of the National Instruments Web site at ni.com for technical support and professional services:

- **Support**—Online technical support resources at ni.com/support include the following:
  - **Self-Help Resources**—For answers and solutions, visit the award-winning National Instruments Web site for software drivers and updates, a searchable KnowledgeBase, product manuals, step-by-step troubleshooting wizards, thousands of example programs, tutorials, application notes, instrument drivers, and so on.
  - **Free Technical Support**—All registered users receive free Basic Service, which includes access to hundreds of Application Engineers worldwide in the NI Developer Exchange at ni.com/exchange. National Instruments Application Engineers make sure every question receives an answer.

    For information about other technical support options in your area, visit ni.com/services or contact your local office at ni.com/contact.
- **Training and Certification**—Visit ni.com/training for self-paced training, eLearning virtual classrooms, interactive CDs, and Certification program information. You also can register for instructor-led, hands-on courses at locations around the world.
- **System Integration**—If you have time constraints, limited in-house technical resources, or other project challenges, National Instruments Alliance Partner members can help. To learn more, call your local NI office or visit ni.com/alliance.
- **Declaration of Conformity (DoC)**—A DoC is our claim of compliance with the Council of the European Communities using the manufacturer's declaration of conformity. This system affords the user protection for electronic compatibility (EMC) and product safety. You can obtain the DoC for your product by visiting ni.com/certification.

- **Calibration Certificate**—If your product supports calibration, you can obtain the calibration certificate for your product at `ni.com/calibration`.

If you searched `ni.com` and could not find the answers you need, contact your local office or NI corporate headquarters. Phone numbers for our worldwide offices are listed at the front of this manual. You also can visit the Worldwide Offices section of `ni.com/niglobal` to access the branch office Web sites, which provide up-to-date contact information, support phone numbers, email addresses, and current events.

Glossary

Symbol	Prefix	Value
p	pico	10^{-12}
n	nano	10^{-9}
µ	micro	10^{-6}
m	milli	10^{-3}
k	kilo	10^{3}
M	mega	10^{6}
G	giga	10^{9}
T	tera	10^{12}

Numbers/Symbols

°	Degree.
–	Negative of, or minus.
Ω	Ohm.
/	Per.
%	Percent.
±	Plus or minus.
+	Positive of, or plus.
+5V	+5 V output signal.

A

A	Amperes.
AC	Alternating current.

AC coupled	Allowing the transmission of AC signals while blocking DC signals.
ADC	Analog-to-digital converter—an electronic device that converts an analog voltage to a digital number.
AGND	Analog ground signal.
ANSI	American National Standards Institute.
AT bus	*See* bus.
attenuation	Decreasing the amplitude of a signal.
Auto Zeroing	The process of removing an offset error from a measurement.
AWG	American Wire Gauge.

B

b	Bit—one binary digit, either 0 or 1.
B	Byte—eight related bits of data, an eight-bit binary number. Also used to denote the amount of memory required to store one byte of data.
bandwidth	The range of frequencies present in a signal, or the range of frequencies to which a measuring device can respond.
bipolar	A signal range that includes both positive and negative values (for example, –5 V to +5 V).
buffer	Temporary storage for acquired or generated data (software).
bus	The group of signals that interconnect individual circuitry in a computer. Typically, a bus is the expansion vehicle to which I/O or other instruments are connected. Examples of PC buses are the AT bus (also known as the ISA bus) and the PCI bus.

C

C	Celsius.
CH	Channel.

channel	Pin or wire lead to which you apply or from which you read the analog or digital signal. Analog signals can be single-ended or differential. For digital signals, you group channels to form ports. Ports usually consist of either four or eight digital channels.
clock	Hardware component that controls timing for reading from or writing to groups.
CMOS	Complimentary metal oxide semiconductor.
CMR	Common-mode rejection.
CompactPCI	Refers to the core specification defined by the PCI Industrial Computer Manufacturer's Group (PICMG).
coupling	The manner in which a signal is connected from one location to another.
CPU	Central processing unit.

D

DAQ	Data acquisition—(1) Collecting and measuring electrical signals from sensors, transducers, and test probes or fixtures and inputting them to a computer for processing. (2) Collecting and measuring the same kinds of electrical signals with A/D and/or DIO devices plugged into a computer, and possibly generating control signals with D/A and/or DIO devices in the same computer.
dB	Decibel—the unit for expressing a logarithmic measure of the ratio of two signal levels: $dB = 20 \times \log_{10}(V_1 / V_2)$ for signals in volts.
DC	Direct current.
DC coupled	Allowing the transmission of both AC and DC signals.
device	A plug-in data acquisition product, card, or pad that can contain multiple channels and conversion devices. Plug-in products and devices such as the DAQPad-1200, which connects to your computer parallel port, are all examples of DAQ devices. SCXI modules are distinct from devices, with the exception of the SCXI-1200, which is a hybrid.
DGND	Digital ground signal.
DIO	Digital input and output.

drivers — Software that controls a specific hardware device such as a DAQ device or a GPIB interface.

dynamic range — The ratio of the largest signal level a circuit can handle to the smallest signal level it can handle (usually taken to be the noise level), normally expressed in decibels.

E

EEPROM — Electrically erasable programmable read-only memory—ROM that can be erased with an electrical signal and reprogrammed.

EMF — Electromotive force.

event — The condition or state of an analog or digital signal.

F

filters — Digital or analog circuits that change the frequency characteristics of a signal.

ft — Feet.

G

gain — Factor by which a signal is amplified, sometimes expressed in decibels.

GND — Ground.

H

hardware — Physical components of a computer system, such as the circuit boards, plug-in boards, chassis, enclosures, peripherals, cables, and so on.

Hz — Hertz—the number of scans read or updates written per second.

I

I/O	Input/output—the transfer of data to/from a computer system involving communications channels, operator interface devices, and/or data acquisition and control interfaces.
IC	Integrated circuit.
I_{EXx}	Voltage excitation signal.
in.	Inches.
interrupt	A computer signal indicating that the CPU should suspend its current task to service a designated activity.
ITS	International Temperature Scale.

K

K	(1) Kelvin. (2) Kilo—the prefix for 1,024, or 2^{10}, used with B in quantifying data or computer memory.
kbytes/s	A unit for data transfer that means 1,000 or 10^3 bytes/s.
kS	1,000 samples.

L

LabVIEW	A graphical programming language.
latch	Digital device that stores the digital data based on a control signal.
LED	Light-emitting diode.

M

m	Meters.
M	(1) Mega, the standard metric prefix for 1 million or 10^6, when used with units of measure such as volts and hertz. (2) Mega, the prefix for 1,048,576, or 2^{20}, when used with B to quantify data or computer memory.

MB	Megabytes of memory.
Mbytes/s	A unit for data transfer that means 2^{20} or 1,048,576 bytes/s.
Measurement & Automation Explorer (MAX)	A controlled centralized configuration environment that allows you to configure all of your National Instruments DAQ, GPIB, IMAQ, IVI, Motion, VISA, and VXI devices.

N

NI-DAQ	National Instruments driver software for DAQ hardware.
NIST	National Institute of Standards and Technology.
NMR	Normal-mode rejection.
noise	An undesirable signal—electrical noise comes from external sources such as the AC power line, motors, generators, transformers, fluorescent lights, soldering irons, CRT displays, computers, electrical storms, welders, radio transmitters, and internal sources such as semiconductors, resistors, and capacitors. Noise corrupts signals you are trying to send or receive.
NPN	Type of bipolar transistor.
NTC	Negative temperature coefficient.

O

operating system	Base-level software that controls a computer, runs programs, interacts with users, and communicates with installed hardware or peripheral instruments.

P

PCI	Peripheral Component Interconnect—a high-performance expansion bus architecture originally developed by Intel to replace ISA and EISA. It is achieving widespread acceptance as a standard for PCs and workstations and offers a theoretical maximum transfer rate of 132 Mbytes/s.
peak-to-peak	A measure of signal amplitude—the difference between the highest and lowest excursions of the signal.
PLC	Power line cycles.

PLF	Power line frequency.
plug-and-play devices	Devices that do not require dip switches or jumpers to configure resources on the devices—also called switchless devices.
port	(1) A communications connection on a computer or remote controller; (2) A digital port, consisting of four or eight lines of digital input and/or output.
PTC	Positive temperature coefficient.
PXI	A rugged, open system for modular instrumentation based on CompactPCI, with special mechanical, electrical, and software features.

R

reading rate	The rate, in hertz, at which each sample is updated.
resolution	The smallest signal increment that can be detected by a measurement system. Resolution can be expressed in bits, in proportions, or in percent of full scale. For example, a system has 24-bit resolution, one part in 2^{24} = 16,777,216 resolution, and 5.96×10^{-6}% of full scale.
rms	Root mean square—the square root of the average value of the square of the instantaneous signal amplitudes; a measure of signal amplitude.
RSVD*x*	Reserved.
RTD	Resistance temperature detector—a metallic probe that measures temperature based upon its resistance.

S

s	Second.
S	Sample.
S/s	Samples per second—used to express the rate at which an NI 435*x* samples an analog signal.
sigma-delta	Technology used for analog to digital conversion.
sinter	To cause to become a coherent mass by heating without melting.

system noise	A measure of the amount of noise seen by an analog circuit or an ADC when the analog inputs are grounded.

T

thermistor	A semiconductor sensor that produces a repeatable change in electrical resistance as a function of temperature. Most thermistors have a negative temperature coefficient (NTC).
thermocouple	A temperature sensor created by joining two dissimilar metals. The junction produces a small voltage as a function of the temperature.
TTL	Transistor-transistor logic.

U

update	One or more analog or digital output samples. Typically the number of output samples in an update is equal to the number of channels in the output group.
update rate	The rate at which the measurement data is updated.
USB	Universal Serial Bus.

V

V	The basic unit of electromotive force, or electric “pressure” that causes electric current to flow. One volt is defined as the electromotive force to make one ampere current flow through a one ohm resistor.
VI	Virtual instrument—(1) A combination of hardware and/or software elements, typically used with a PC, that has the functionality of a classic standalone instrument; (2) A LabVIEW software module (VI), which consists of a front panel user interface and a block diagram program.
virtual channels	Channel names that can be defined outside the application and used without having to perform scaling operations.

Index

Numerics

4-wire ohms measurement mode
    purpose and use, 2-2
    range selection, 2-2

A

AC noise effects, minimizing
    DC voltage measurement, 2-13
    RTDs, thermistors, and resistors, 2-27
    thermocouples, 2-10
accuracy specifications
    calculation examples, A-6
    DC voltage (table), A-4
    RTD (tables), A-3
    thermistor (table), A-4
amplifier characteristics, A-7
analog input specifications
    amplifier characteristics, A-7
    dynamic characteristics, A-8
    excitation, A-8
    input characteristics, A-7
auto-zero optimization
    DC voltage measurement, 2-12
    RTDs, thermistors, and resistors, 2-25
    thermocouples, 2-9

B

bus interface specifications, A-9

C

calibration certificate (NI resources), C-2
Callendar-Van Dusen coefficients (table), 2-22
cold-junction
    effect of (figure), 2-7
CompactPCI, using with PXI, 1-2
conventions used in the manual, *ix*
current source, 2-14

D

DC voltage accuracy (table), A-4
DC voltage measurement
    connecting DC voltage signal, 2-11
    input ranges, 2-11
    optimizing measurements
        AC noise effects, 2-13
        auto-zero method, 2-12
        programmable gound-referencing, 2-12
        programmable open-thermocouple detection, 2-12
        source impedance, 2-13
        thermal EMF, 2-13
Declaration of Conformity (NI resources), C-1
diagnostic tools (NI resources), C-1
digital I/O and alarm output specifications, A-9
digital inputs and outputs
    connecting, 2-29
    DIO application examples (figure), 2-29
    inadequate number of input lines (note), 2-30
    logic family thresholds (table), 2-30
    preventing safety hazards (caution), 2-29
documentation
    conventions used in manual, *ix*
    NI resources, C-1
    related documentation, *x*
drivers (NI resources), C-1
dynamic characteristics, A-8

E

equipment, optional, 1-13
examples, *x*
examples (NI resources), C-1
excitation specifications, A-8
external circuits, connecting to, 2-26

F

floating signal source, 2-4

G

ground-referenced signal source, 2-4
ground-referencing, programmable
    optimizing measurements
        DC voltage measurement, 2-12
        RTDs, thermistors, and resistors, 2-26
        thermocouples, 2-9
    purpose and use, 2-5
    settings (table), 2-5

H

help, technical support, C-1

I

input ranges
    DC voltage measurement, 2-11
    resistance measurement, 2-16
    thermocouples, 2-8
instrument drivers (NI resources), C-1

K

KnowledgeBase, C-1

L

LEDs for NI 4350 (USB)
    patterns (table), 1-7

M

measurement mode, choosing, 2-1

N

National Instruments support and services, C-1
NI 4350 (USB), LEDs, patterns (table), 1-7
NI 435*x,* examples, *x*
NI 435*x* instruments
    See also operation of NI 435*x* instruments
    optional equipment, 1-13
    overview, 1-1
    using PXI with CompactPCI, 1-2
NI support and services, C-1
noise effects, AC. *See* noise effects, minimizing

O

open-thermocouple detection, programmable
    optimizing measurements
        DC voltage measurement, 2-12
        RTDs, thermistors, and resistors, 2-26
        thermocouples, 2-10
    settings (table), 2-6

operation of NI 435*x* instruments
current source, 2-14
DC voltage measurement
connecting DC voltage signal, 2-11
input ranges, 2-11
optimizing measurements, 2-12
digital inputs and outputs, 2-28
measurement mode selection, 2-1
programmable ground-referencing, 2-5
programmable open-thermocouple detection, 2-5
range selection, 2-2
reading rate selection, 2-2
resistance measurement
input ranges, 2-16
optimizing measurements, 2-25
RTDs for measuring temperature
connecting, 2-14
optimizing measurements, 2-25
relationship of resistance and temperature, 2-20
signal sources
floating signal source, 2-4
ground-referenced signal source, 2-4
thermistors for measuring temperature
connecting thermistors, 2-25
optimizing measurements, 2-25
resistance-temperature characteristics, 2-24
thermocouples for measuring temperature
connecting thermocouple, 2-8
input ranges, 2-8
optimizing measurements, 2-8
optimizing measurements
DC voltage
AC noise effects, 2-13
auto-zero method, 2-12
programmable ground-referencing, 2-12
programmable open-thermocouple detection, 2-12
source impedance, 2-13
thermal EMF, 2-13
RTDs, thermistors, and resistors
AC noise effects, 2-27
auto-zero method, 2-25
connecting to external circuits, 2-26
guidelines for resistance measurement (table), 2-26
programmable ground-referencing, 2-26
programmable open-thermocouple detection, 2-26
self-heating, 2-27
themal EMF, 2-28
two-wire, three-wire, and four-wire measurements, 2-26
thermocouples
AC noise effects, 2-10
auto-zero method, 2-9
programmable ground-referencing, 2-9
programmable open-thermocouple detection, 2-10
thermal EMF, 2-11
optional equipment, 1-13

P

physical specifications, A-10
power requirements, A-9
programmable ground-referencing. *See* ground-referencing, programmable
programmable open-thermocouple detection. *See* open-thermocouple detection, programmable
programming examples (NI resources), C-1
PXI, using with CompactPCI, 1-2

R

range selection, for measurement mode, 2-2
reading rate selection
  determining reading rate per channel (note), 2-3
  filtering and sample rates (table), 2-4
reference junction, 2-6
related documentation, *x*
resistance measurement
  connecting resistors
    multiple transducer connections to analog channels (figures), 2-18
    preventing safety hazards (caution), 2-17
  input ranges, 2-16
  optimizing
    AC noise effects, 2-27
    auto-zero method, 2-25
    connecting to external circuits, 2-26
    guidelines for resistance measurement (table), 2-26
    programmable ground-referencing, 2-26
    programmable open-thermocouple detection, 2-26
    self-heating, 2-27
    thermal EMF, 2-28
    two-wire, three-wire, and four-wire measurements, 2-26
  RTDs
    connecting, 2-14
    relationship of resistance and temperature, 2-20
  thermistors
    connecting, 2-25
    resistance-temperature characteristics, 2-24
RTDs
  accuracy specifications (tables), A-3
  Callendar-Van Dusen coefficients (table), 2-22
  connecting
    four-wire RTD measurement (figure), 2-15
    three-wire RTD measurement (figure), 2-15
    two-wire RTD measurement (figure), 2-14
  definition, 2-20
  measuring temperature, 2-20
  optimizing measurements, 2-25
  relationship of resistance and temperature, 2-20
  resistance-temperature curve (figure), 2-21

S

self-heating, errors due to, 2-27
signal connections
  using the NI 435*x* (ISA, USB, PXI, PCI) with the TBX-68 (table), B-1
signal sources
  floating signal source, 2-4
  ground-referenced signal source, 2-4
software (NI resources), C-1
source impedance, DC voltage measurement, 2-13
specifications
  accuracy
    calculation examples, A-6
    DC voltage (table), A-4
    RTD (tables), A-3
    thermistor (table), A-4
  analog input
    amplifier characteristics, A-7
    dynamic characterics, A-8
    excitation, A-8
    input characteristics, A-7

bus interface, A-9
digital I/O and alarm outputs, A-9
physical, A-10
power requirements, A-9

T

technical support, C-1
temperature measurement
RTDs
connecting, 2-14
optimizing measurements, 2-25
relationship of resistance and temperature, 2-20
thermistors
connecting, 2-25
optimizing measurements, 2-25
resistance-temperature characteristics, 2-24
thermocouples
cold-junction effect (figure), 2-7
connecting, 2-8
input ranges, 2-8
optimizing measurements, 2-8
thermal EMF, minimizing
DC voltage measurement, 2-13
RTDs, thermistors, and resistors, 2-28
thermocouples, 2-11
thermistors
accuracy specifications (table), A-4
advantages and disadvantages, 2-23
connecting, 2-25
optimizing measurements, 2-25
resistance-temperature characteristics, 2-24
resistance-temperature curve (figure), 2-24
types of thermistors, 2-23
thermocouples for measuring temperature
accuracy specifications (table), A-1
cold-junction effect (figure), 2-7
connecting, 2-8
input ranges, 2-8
optimizing measurements
AC noise effect, 2-10
auto-zero method, 2-9
programmable ground-referencing, 2-9
programmable open-thermocouple detection, 2-10
thermal EMF, 2-11
overview, 2-6
training and certification (NI resources), C-1
troubleshooting (NI resources), C-1

V

volts measurement mode
range selection, 2-2

W

Web resources, C-1